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GEOLOGY OF THE MID CONTINENT OILFIELDS

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KEY TO THE GENERAL MAP

Suggestion.

To bring out the geology plainly, this map may be colored with crayon or water color.

Cretaceous	**may be colored**	**pale yellow.**
Permian	**may be colored**	**pale green.**
Pennsylvanian	**may be left**	**white.**
Mississippian and Older	**may be colored**	**pale pink.**

OILFIELDS REPRESENTED BY THE NUMBERS ON THE MAP

OILFIELDS IN KANSAS:

11	Bonner Springs,	Wyandotte County.
12	Olathe,	Johnson County.
13	Rantoul,	Franklin County.
14	Paola,	Miami County.
15	Greeley,	Anderson County.
16	Mound City,	Linn County.
17	Neosho Falls,	Woodson County.
20	Iola,	Allen County.
21	Moran,	Allen County.
22	Potwin,	Butler County.
23	Eldorado,	Butler County.
23	Towanda,	Butler County.
24	Augusta,	Butler County.
25	Douglas,	Butler County.
26	Sallyards,	Greenwood County.
27	Toronto,	Woodson County.
30	Humboldt,	Allen County.
30	Chanute,	Neosho County.
31	Erie,	Neosho County.
32	Altoona,	Wilson County.
32	Freedonia,	Wilson County.
33	New Albany,	Wilson County.
34	Thayer,	Neosho County.
35	Neodesha,	Wilson County.
36	Greenola,	Elk County.
37	Longton,	Elk County.
37	Elk City,	Montgomery County.
40	Cherryvale,	Montgomery County.
41	Coffeyville,	Montgomery County.
41	Mound Valley,	Labette County.
42	Independence,	Montgomery County.
42	Bolton,	Montgomery County.
42	Wayside,	Montgomery County.
42	Caney,	Montgomery County.

42	Tyro,	Montgomery County.
43	Hale,	Chautauqua County.
44	Peru,	Chautauqua County.
44	Sedan,	Chautauqua County.
45	Winfield,	Cowley County.
46	Arkansas City,	Cowley County.
50	Oswego,	Labette County.

OILFIELDS IN OKLAHOMA:

51	Blackwell,	Kay County.
52	Newkirk,	Kay County.
53	Mervine,	Kay County.
54	Ponca City,	Kay County.
55	Billings,	Noble County.
56	Garber,	Garfield County.
57	Pawhuska,	Osage County.
60	Canary-Copan,	Washington County.
60	Dewey,	Washington County.
60	Bartlesville.	Washington County.
60	Wann,	Washington County.
61	California Creek,	Nowata County.
62	Delaware-Childers,	Nowata County.
62	Adair,	Nowata County.
62	Nowata,	Nowata County.
62	Canary,	Washington County.
63	Claggett,	Nowata County.
63	Coodys Bluff-Alluwe-Chelsea	Nowata County. Rogers County.
65	Hogshooter,	Washington County.
66	Bigheart,	Osage County.
66	Wynona,	Osage County.
67	Avant,	Osage County.
68	Ochelata,	Osage County.
68	Vera,	Washington County.
70	Hominy,	Osage County.
71	Boston,	Osage County.
71	Cleveland,	Pawnee County.
72	Bird Creek,	Tulsa County.
72	Flat Rock,	Tulsa County.
73	Collinsville-Owasso,	Rogers County. Tulsa County.
73	Catoosa,	Rogers County.

73	Claremore,	Rogers County.
75	Inola,	Rogers County.
76	Coweta,	Wagoner County.
76	Stone Bluff,	Wagoner County.
77	Wagoner,	Wagoner County.
80	Broken Arrow,	Tulsa County.
81	Glen Pool,	Creek County. Tulsa County.
81	Red Fork,	Tulsa County.
81	Jenks,	Tulsa County.
81	Tanaha,	Tulsa County.
81	Kelleyville,	Creek County.
82	Cushing,	Creek County.
83	Yale,	Payne County.
83	Quay,	Payne County.
84	Bristow,	Creek County.
86	Bixby,	Tulsa County.
86	Mounds,	Okmulgee County.
87	Beggs,	Okmulgee County.
87	Preston (Hamilton Switch),	Okmulgee County.
90	Baldhill,	Okmulgee County.
91	Creekola,	Muskogee County.
92	Muskogee,	Muskogee County.
93	Boynton,	Muskogee County.
94	Booch,	Okmulgee County.
94	Okmulgee,	Okmulgee County.
94	Morris,	Okmulgee County.
95	Youngstown,	Okmulgee County.
95	Tiger Flats,	Okmulgee County.
96	Bartlett,	McIntosh County. Okmulgee County.
96	Henryetta-Schulter,	Okmulgee County.
100	Stedham,	McIntosh County.
100	Checotah,	McIntosh County.
101	Dustin,	Hughes County.
104	Spiro,	Le Flore County.
105	Poteau,	Le Flore County.
107	Granite City,	Greer County.
108	Hobart,	Kiowa County.
111	Gotebo,	Kiowa County.
112	Francis,	Ponotoc County.

113	Allen,	Ponotoc County.
114	Coal County,	Coal County.
115	Ada,	Ponotoc County.
116	Duncan-Cruce,	Stephens County.
117	Lawton,	Commanche County.
118	Walters,	Cotton County.
120	Loco,	Stephens County.
121	Fox,	Carter County.
122	Wheeler,	Carter County.
123	Healdton,	Carter County.
123	Hewitt,	Carter County.
124	Madill,	Marshall County.
125	Lark,	Marshall County.

GASFIELDS IN ARKANSAS:

102	Kibler,	Crawford County.
103	Fort Smith	Sebastian County.
	(Massard Prairie),	Scott County.
106	Mansfield,	

OILFIELDS IN NORTH TEXAS:

201	Electra,	Wichita County.
201	Burkburnett,	Wichita County.
202	Iowa Park,	Wichita County.
203	Petrolia,	Clay County.
204	Archer,	Archer County.
205	Antelope,	Jack County.
206	Young County,	Young County.
207	Palo Pinto,	Palo Pinto County.
208	Holliday,	Archer County.
210	New Caddo,	Stephens County.
211	Breckenridge,	Stephens County.
212	Moran,	Shackleford County.
213	Strawn,	Palo Pinto County.
214	Ranger,	Eastland County.
215	Desdemona (Duke-Knowles),	Commanche County.
216	Burkett,	Coleman County.
217	Coleman,	Coleman County.
217	Santa Anna,	Coleman County.
218	Brownwood,	Brown County.

GEOLOGY

OF THE

MID CONTINENT OILFIELDS

KANSAS, OKLAHOMA AND NORTH TEXAS

BY

T. O. BOSWORTH

D.SC. (LONDON), M.A. (CAMBRIDGE), F.G.S., F.R.G.S.,
MEMBER OF THE INSTITUTION OF PETROLEUM TECHNOLOGISTS
FORMERLY OF H.M. GEOLOGICAL SURVEY OF GREAT BRITAIN

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GEOLOGY OF THE MID CONTINENT OILFIELDS

PART I

INTRODUCTION AND BIBLIOGRAPHY

CHAPTER I

INTRODUCTION

The Mid Continent Oilfield region is the greatest of the world's developed oil territories. During the past three years, 1917–1919, the annual yield (140–180 million barrels), has been nearly one-third of the world's production; and already almost one-sixth of all the oil yet taken out of the earth has been supplied by these fields (1,266 million barrels out of 8,057 million barrels).

The study of this territory, therefore, is of much importance to the science of Geology. It is the object of this book to set forth the facts, and to review them.

The author is aware of the incompleteness of his own knowledge of this great subject. The facts have been drawn from many sources. Free use has been made of the bulletins of the United States Geological Survey and those of the State Geological Surveys of Kansas, Oklahoma, and Texas; also of the leading oil journals. The names of many of the geologists and observers who have thus indirectly contributed to this volume can be read in the list of works enumerated below. To these, and many others whose researches have advanced our understanding of this field, the author's acknowledgments are due.

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PART II

GEOGRAPHICAL AND GEOLOGICAL SITUATION OF THE MID CONTINENT OIL REGION

The Mid Continent Oil Region, as dealt with in this book, is fairly well defined and has a natural geological boundary. It includes all the oilfields of Kansas and Oklahoma, together with nearly all those of the northern part of Texas. The oil is obtained from the rocks of the Carboniferous and Permian Systems.

In oil literature these fields have not regularly been grouped altogether, but often are scattered under different titles, such as "North Mid Continent" and "South Mid Continent," "Gulf Oilfields," "North Texas," "North Central Texas," "Texas Pan-handle," etc., or according to States.

In the latest official publications on production, the statistics will be found partly under State headings, but chiefly under "Mid Continent Oilfield" with subdivisions "Kansas," "Oklahoma" and "North Texas and North Louisiana." Geologically this is not satisfactory, for we need to exclude all the North Louisiana fields and several* of the North Texas fields, because these are outside the natural geological boundary, operating in an entirely different formation and obtaining a different kind of oil.

* Corsicana, Marion County, Powell & Thrall.

The Mid Continent Oilfields occupy a broad strip of territory, some 550 miles in length, extending for 250 miles southward along the eastern side of Kansas and Oklahoma and continuing southwestward for 100 miles in southern Oklahoma and a further 200 miles southwest into the center of Texas.

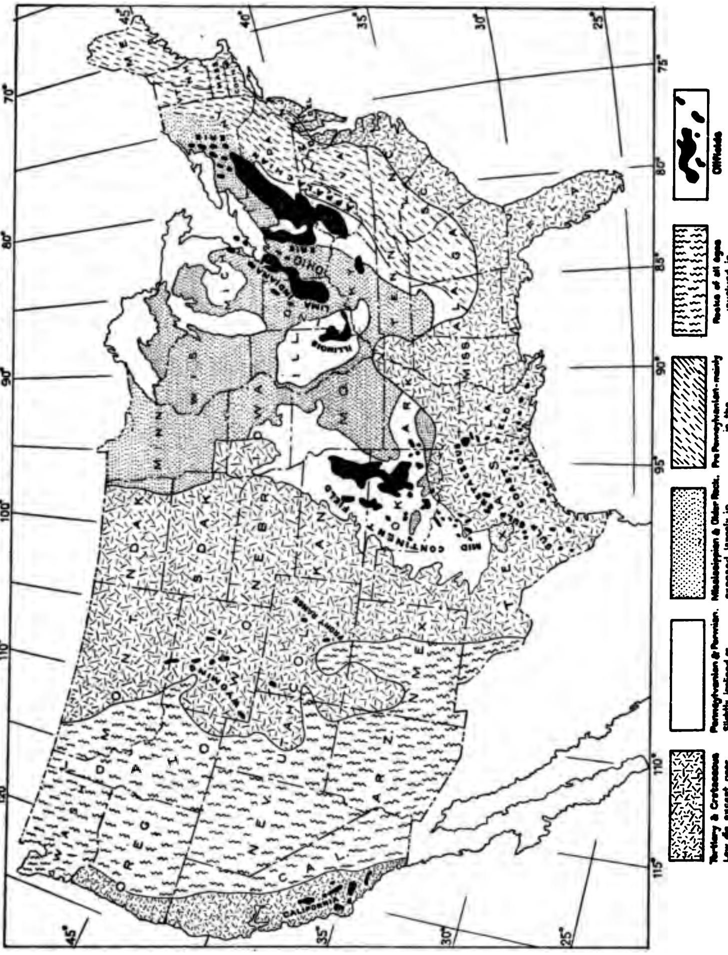

Tertiary & Cretaceous
Low dip except near the Mountain ranges.
Pennsylvanian & Permian.
Slightly inclined or occupying synclinals.
Mississippian & Older Rock.
exposed largely in anticlinal region.
Pre Pennsylvanian-mainly in the Appalachian folds.
Rocks of all ages involved in Rocky Mountain folds
Oilfields
Mid Continent
California
Illinois
Lima
Ohio
Appalachian
Wyoming
Big Horn Basin

FIG. 2. OILFIELDS OF UNITED STATES

Surroundings of the Mid Continent Oilfield.

The Mid Continent Oilfield Region is bounded on the northeast and east by a region of Mississippian (Lower Carboniferous) and older rocks, known as the Ozark Uplift.

For the remainder of the distance around—southeast, west and northwest, it is bordered by the present margin of the Cretaceous and Tertiary deposits, which lie unconformably over the Pennsylvanian.

Neighboring Oil Regions.

The nearest oilfield region to eastward is that of Missouri, which also produces from the Pennsylvanian System, but is completely separated from the Mid Continent Field by the Ozark Mountain Uplift.

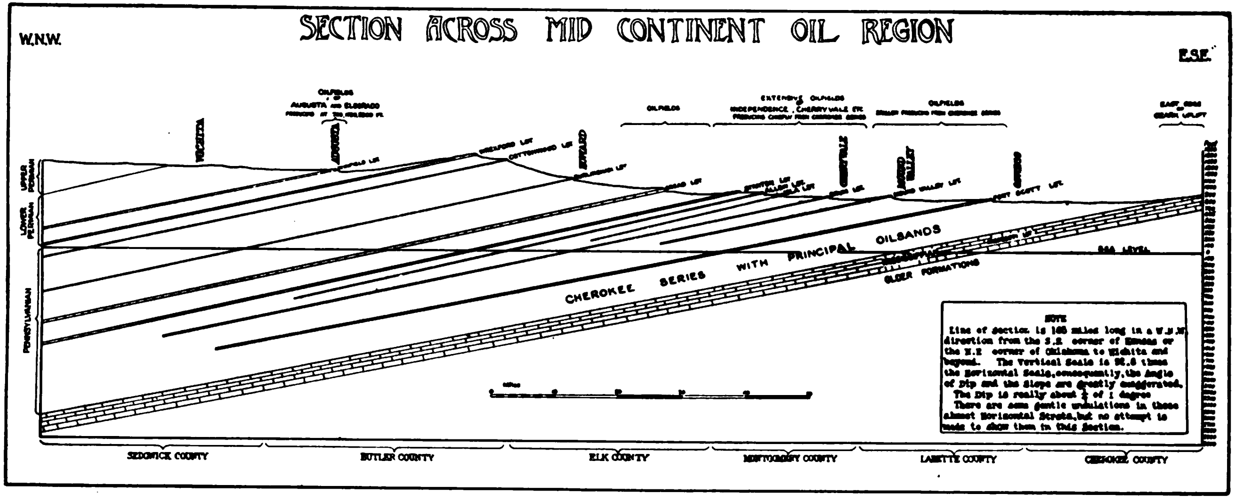
To the south and southeast there are, in Texas, the small oilfields near San Antonio and Thrall and the oilfield of Corsicana; and in Louisiana there is the Caddo field—all of which produce from the Cretaceous formations and belong to the "Gulf Cretaceous" group of oilfields. The nearest of these lies at a distance of 120 miles. Beyond them, still farther southward, are the great fields of the Gulf Coast, associated with the salt domes in the Tertiary deposits.

To westward, at a far distance, there are the oilfield regions of Wyoming and the Rocky Mountains, in which oil is found mainly in the Cretaceous.

Geological Position of the Oilfields.

The fields are situated on the Prairie Plains Monocline, chiefly along the outcrop of the Pennsylvanian (Carboniferous) System. Geologically, the province also extends northward into a small part of Iowa, Nebraska and Missouri, and southeastward into Arkansas; but oil production has not been found in those districts.

Fig. 3.



NOTE

Line of section is 165 miles long in a W.N.W. direction from the S.E. corner of Kansas or the N.E. corner of Oklahoma to Wichita and beyond. The Vertical Scale is 52.8 times the Horizontal Scale, consequently, the Angle of Dip and the Slope are greatly exaggerated. The Dip is really about ½ of 1 degree. There are some gentle undulations in these almost Horizontal Strata, but no attempt is made to show them in this Section.

This great, isolated expanse of Pennsylvanian rocks embraces the regions known to the coal mining industry as the Western Interior Coalfield and the Southwestern Interior Coalfield.

The attitude of the Pennsylvanian System of America is much the same as that of the Upper Carboniferous of Britain, that is, it now occupies structural basins—not necessarily having been specially deposited in "basins," but rather having been specially preserved by them. In the United States, these basins of immensely greater size than in Britain. The Western Interior Coal Field (or Prairie Plains Monocline) is one of the largest of these. We might regard this monocline, in which the Mid Continent Oil Fields lie, as the eastern limb of a geo-synclinal, whose western limb is concealed under the Cretaceous of the West. By some, however, it is viewed as the western limb of an anticlinal which has the Ozark uplift for its core.

PART III

HISTORY OF THE DEVELOPMENT OF THE MID CONTINENT OIL REGION

DISCOVERY OF THE OILFIELDS

The oil wealth of the Mid Continent Field is of recent discovery. The sum total of all oil produced, previous to the year 1903, was less than a million barrels. But from that date onwards the development was very rapid and during the past six years, 1914–1919, there has been an annual production of from 100 to 180 million barrels, which is more than one-fourth of the world's output.

The history of these oilfields is young though the usual stories of seepages known to the Indians date back far into the past.

The first commercial oil wells were in Kansas, where, as long ago as 1889, 500 barrels of oil were marketed, and in 1896 there was a production of 113,571 barrels.

DEVELOPMENT, 1903-1905

It was not until 1903 and 1904 that the extensive exploitation commenced. The large oilfields or pools around Erie, Independence, Neodesha, Coffeyville, Peru, Sedan, Chanute, Humboldt, Caney, Wayside, were developed chiefly in those years.

The oil pools which were first opened, naturally were those lying at small depth. They occur along the eastern edge of the region, on or near the outcrop of the Cherokee Series, which is the lowest member of the Pennsylvanian System. Although so shallow, their yield was great: thus, in the Independence field, where the depth was but 450–600 feet, there were many wells giving 1,000 barrels per day, and the larger of these fields contained thousands of wells. In 1904, Kansas produced 4¼ million barrels of oil.

Some of the fields at first were most prominent as gas fields, such as Iola, Independence and Cherryvale, with wells giving 15–30 million cubic feet of gas per day.

During 1904 and 1905, important oilfields were being discovered and opened up in Oklahoma; and their output soon greatly exceeded that of Kansas.

The Coody's Bluff-Alluwe fields were among the first of the Oklahoma pools; and here were wells from 300–600 feet deep, which would flow at the rate of 500 barrels a day, for a month or more.

Other pools exploited in 1904–1905 were those of Red Fork, 700 to 1,000 feet deep, Dewey-Bartlesville, 800 to 1,600 feet deep which had many thousand-barrel wells, and the Cleveland field 1,600 to 1,900 feet deep. Until this time almost all the production was obtained from the sands of the Cherokee Series, but in these more western fields, oil was found in the sands of the Bandera, Coffeyville and Wilson Series. In the Cleveland field especially, a large yield of oil came from the Cleveland Sand, about 500 feet above the top of the Cherokee. In subsequent years the drilling in such fields was carried deeper down to the sands of the Cherokee formation, where generally a greater supply was found. In 1905 the production of the Mid Continent Field exceeded 12½ million barrels.

Production in the North Texas part of the region also was developed in 1904–1905 by the opening of the Petrolia field. Here, in 1904 some 75 wells were drilled, obtaining yields of from 3 to 40 barrels a day from a sand at 300 feet; and in 1905 there was an output of 100,000 barrels.

DEVELOPMENT, 1906-1911

The famous Glen pool of Oklahoma was opened in 1906–1907, yielding about 20 million barrels a year during the period 1907–1910, the maximum being reached in October, 1907, during which month an average of about 80,000 barrels a day was maintained. The total production of the Glen pool up to the end of 1919 has amounted to 153 million barrels from an area of about 30 square miles. The oil was found generally in a thick sand known as the Glen Sand at 1,500 feet, which may be the same as the Bartlesville Sand. There was also a large yield from the Red Fork Sand, about 150 feet above. Many of the wells flowed at the rate of more than 2,000 barrels, daily.

The Morris, Hogshooter and Muskogee fields were developed chiefly in 1907–1908, and the production of the Mid Continent Fields for 1907 was 46 million barrels, of which Kansas contributed $3^1/_3$ millions.

In north Texas the valuable gas sands of Petrolia, at 1500–1750 feet were explored in the years 1907–1909 by deeper drilling in that oilfield, and in 1909 the gas was piped to Dallas and Fort Worth. This has been the principal gas-field of that part of the region. The development of the large oilfields of Wichita County, commenced with the opening of the Electra pool in 1910. The discovery of the adjoining fields of Burkburnett and Iowa Park followed in 1912 and 1913, though they did not contribute largely to the production until later years.

DEVELOPMENT, 1912-1915

In 1912 there was deeper drilling in Oklahoma and much oil was obtained by exploration of the deeper sands in the Cleveland field. The Adair pool also was opened.

But the great event of the year was the discovery of the prolific Cushing field. This field, which is six years younger than the Glen field, has now given considerably more oil. The total yield up to the end of 1919 is almost 236 million barrels, from an area of 36 square miles. The oil was found first in the Layton Sand at 1,400 feet and then in the Wheeler Sand at 2,175 feet; but in 1914 the development was mainly in the Bartlesville Sand at 2,600 feet, where a much greater yield was obtained, many wells giving as much as 10,000 barrels of oil a day.

In the next year, 1913, the most important news was the opening of the Healdton field, where 270 producers were drilled in the last four months of the year. This field, which obtains its oil from the Permian rocks, has grown steadily, until in 1917 it was one of the greatest in the country and comparable with Glen and Cushing; but the production is now declining. Up to the end of 1919 about 127 million barrels of oil were obtained from an area of 13 square miles.

In 1914 the Moran field in north Texas, which was discovered the previous year, became a regular producer and indicated further prospects in that region.

In 1915, all other happenings were overshadowed by the great expansion of the Cushing field, already referred to, which reached its maximum production in the month of April, making 300,000 barrels a day. The official records for oil marketed from the Cushing field in that year show 49 million barrels, but besides this, a great quantity went into storage, and it is estimated that the total quantity produced in 1914 was nearly 74 million barrels. This field has also been the greatest producer of natural gas in the region.

There was also an important growth in the Healdton field which was yielding 90,000 barrels a day early, in the year.

In north Texas the Strawn field was opened in 1915 and has since become a valuable contributor.

DEVELOPMENT, 1916-1917

During 1916 and 1917 the maximum activity reverted to Kansas with the discovery of the pools at Augusta, Eldorado and Towanda, 70 miles west of the older fields. These new fields proved so rich that the Kansas production rose quickly to 11½ million barrels in 1916 and then to 38 million barrels in 1917. Here, previously there was a gasfield, drilled in 1913–1914, in sands lying at a depth of about 1,500 feet. But the principal oil sand, known as the Varner Sand, exploited during the past four years, was found at 2,500 feet; and there is also some production at 1,750 feet. The best wells in the Augusta pool have flowed as much as 12,000–15,000 barrels a day, whilst at Eldorado and Towanda some wells have come in at from 18,000–25,000 barrels a day. At Eldorado there were also some flowing wells in a shallow sand at about 600 feet. By the end of 1919, these Butler County pools had yielded 100 million barrels of oil from an area of about 40 square miles.

In Oklahoma, during 1916–1917, the annual production diminished. A maximum had been reached in 1915 when the figure was near 118 million barrels. This decreased to 97½ million in 1917 and 85 million in 1918. The falling off is due, chiefly, to the decline of the great Cushing pool.

In the same period, however, the output of the Healdton field increased from 5 million to 22 million barrels which was the maximum attained by it. At the same time also some good results were being obtained by deepening and extending the operations in other existing fields. Many of the extensions received new names and are known as individual fields. A full list of the pools would include more than 200 names.

The Yale pool, also discovered by deep drilling west of the Cushing field, became an important producer during 1917. By the end of the year it was yielding half a million barrels a month from a sand at 3,130 feet—believed to be the Bartlesville.

The most notable new territory exploited in Oklahoma during 1916–1917 is that just south of the Kansas Boundary line, in Kay, Noble and Garfield Counties, far west of the older fields. Here, at Blackwell, Newkirk, Ponca, Billings and Garber, fields were opened up, largely in sands at 3,000–3,400 feet depth, presumably belonging to the Cherokee formation.

At Blackwell a number of these deep wells gave initial flows of 1,000–2,000 barrels per day, but also many were costly failures. Much of the production during 1918 was being obtained from sands at about 1800 feet, which at first generally were ignored. The field has produced about 2 million barrels a year for the past two years.

At Newkirk the early production was at 500 feet, but in 1918 the field was being developed in a deep sand at 3,100 feet. Ponca was drilled up first as a gas field at 500 feet and then for oil in a sand at 1500–1600 feet, but in 1918 and 1919 the exploitation was at 2,100 feet and 3,900 feet. The Billings pool became important in 1917 when wells in the 2,100 feet sand came in at 2,000 or 3,000 barrels a day. The Garber pool came into production during the latter part of 1917 and since then has been yielding at the rate of about a million barrels a year from sands between 1,000 and 2,300 feet. The shallow sand at Newkirk and the shallow sand at Eldorado are the highest horizon from which oil has yet been obtained in Kansas and northern Oklahoma. They appear to be within 200 or 300 feet of the top of the Pennsylvanian.

In the south part of Oklahoma, however, at Healdton, etc., the production is from the Red Measures of the Permian System. Along the south border of this State during the past three years there has been a considerable amount of drilling in the Permian and several small new fields were showing promise.

In northern Texas there was much drilling in 1916 and 1917, and the production of that part of the Mid Continent Field was much increased, mainly due to the deeper drilling in the Electra-Burkburnett field where many gushers were obtained giving 1,000 barrels a day or more, from a sand at about 1,700 feet. An interesting shallow field was opened up at Brownwood, Brown County, where at the end of the year, 1917, there were 200 or more producers having depth 200–300 feet, and giving from 10 to 25 barrels a day. During 1918 this field was maintaining an average yield of some 2,000 barrels a day.

DEVELOPMENT, 1918

In 1918 the principal event of the year was the extensive development in north Texas which has followed the discovery of the Ranger pool. The discovery well "came in," in October, 1917, giving 2,000 barrels a day. The producing bed, now known as the Ranger Sand, lies at 3,300–3,500 feet, and is in the "black lime" of the Bend Formation which is regarded as belonging to the Mississippian System. Hundreds of deep holes soon were being drilled in the surrounding counties and a number of new fields were discovered. The oil is of remarkably high quality; and many wells are large producers, some giving 5,000–10,000 barrels a day. At the close of the year 1918, the Ranger field was making 28,000 barrels a day.

There was an important growth also in the older field of Electra-Burkburnett where very rich new territory was proved within the village of Burkburnett. Here many wells were brought in at about 1,800 feet, yielding 2,000 barrels a day or more; and the village quickly grew into a town.

As a result of these new operations the annual output from north Texas was almost doubled in two years, being about 15 million barrels in 1918.

In Oklahoma there was a further decline due to natural falling off in the Healdton, the Osage and the Cushing fields, as well as all the older fields. The Youngstown pool in Okmulgee County, however, gave a heavy production and there was greatly increased output in the newer fields of Yale (Payne County), and Billings, Garber and Blackwell.

In Kansas, during 1918, there was a further large gain in production. The year's output (43¼ million barrels) being more than half as great as that of Oklahoma. This was due mainly to the development of the rich Towanda extension of the Eldorado field. The yield of the Eldorado, Towanda and Augusta fields for the year averaged about 100,000 barrels a day, being 84 per cent of the production of Kansas. In the latter half of the year, however, these fields were declining rapidly.

DEVELOPMENT, 1919

During 1919 there has been a remarkable growth of the oil oilfields of northern Texas, and the year's production in that part of the region is likely to reach 65 million barrels, which is more than 4 times the output for the preceding year.

The new pool at Burkburnett at one time was yielding 100,000 barrels a day, and Ranger maintained a steady production of 70,000 barrels during much of the year. The Desdemona field also has become a large producer.

In Oklahoma the decline was checked, and during the latter half of the year there was a gradual increase which has restored the annual output to near the same figure as in 1917.

The increase is due largely to progress in the Osage and in Okmulgee County. But very few new pools have been discovered. Most of the new ground is in Osage, Okmulgee and Cotton counties. In Cotton county an important new field is being proved.

Deeper drilling is becoming general in many fields, with good results. Garber has been the scene of increased activity, and deeper sands are now being exploited. In the Ponca field an important sand has been found at 3,900 feet, in which a number of 1000–3000 barrel wells are being drilled.

In some districts, notably in the Yale field, in the Osage fields, and in Okmulgee county, an important production is now being developed from horizons in the Mississippi Lime. Thus in the Beggs district, a number of large wells have been obtained in this formation at a depth of 2,700 feet.

In Arkansas there has been considerable growth of the Van Buren gasfield, and at the end of June it was stated there were 50 producers with a combined daily capacity of 130 million cubic feet.

In Kansas there has been a heavy fall in production due to the decline of the Augusta-Eldorado pools.

North of Eldorado, in Butler and Marion counties, an important new field known as the Peabody-Elbing pool has been the place of chief activity. The main oil sand lies at 2,500 feet. Many wells have come in at 500–1,000 barrels, and about the middle of the year there was a daily output of 6,000 barrels.

A prolific gasfield near Elk City has been rapidly developed during the year. In November there were 50 producers with a potential yield of 1,382 million cubic feet a day.

DAILY PRODUCTION—OCTOBER, 1919

(According to the Oil & Gas Journal)

Kansas

El Dorado	47,000
Augusta	11,800
Elbing-Peabody	14,250
Other Fields	16,250
	89,300

Oklahoma

Washington County:	
Bartlesville	4,319
Copan-Wann	1,576
Hogshooter	1,609
Nowata-Rogers Counties:	
Nowata	3,818
Delaware	1,102
Chelsea	1,190
Inola	300
Osage County	42,150
Tulsa County:	
Bird Creek, Skiatook and Owasso	5,980
Lost City, Red Fork, etc.	1,777
Broken Arrow and Jenks	1,400
Bixby and Leonard	2,975
Okmulgee County:	
Mounds	1,703
Beggs, Hamilton Switch and Youngstown	42,100
Bald Hill and Booch Sand	3,890
Okmulgee and Morris	2,200
Henryetta and Schulter	1,615
Tiger Flats	2.900
Muskogee and Wagoner Counties:	
Haskell and Stone Bluff	2,000
Boynton and Cole	1,800
Coweta	400
Muskogee and miscellaneous	760
Creek County:	
Cushing	37,900
Glenn Pool	14,000
Mannford and Olive	940
Kellyville, Bristow and Depew	2,000
Pawnee County:	
Cleveland and Jennings	5,250
Payne County:	
Yale, Quay, etc.	9,560
Kay County:	
Blackwell	4,100
Newkirk-Mervine	1,510
Ponca City	2,445
Garfield and Noble Counties:	
Garber	9,691
Billings	2,240
Carter County:	
Healdton and Fox	35,099
Cotton and Stephens Counties:	
Walters, Duncan, etc.	6,160
Miscellaneous	500
	256,959

North Texas

Burkburnett	83,000
Electra	10,500
Iowa Park	550
Holliday	100
Petrolia	520
Eastland County (Ranger, etc.)	68,000
Stephens County (Breckenridge, New Caddo, etc.)	42,000
Commanche County (Desdemona, etc.)	31,000
Shackleford County (Moran)	110
Coleman County (Coleman, etc.)	130
Brownwood	420
Strawn	180
	236,510

PRODUCTION (*in Barrels*)

Year	*Kansas*	*Oklahoma*	*North Texas*	TOTAL *Mid Continent*	TOTAL *United States*	TOTAL *World*
1859–1900	438,154	4,225		442,379	939,882,576	1,592,916,200
1900	68,564	6,150		74,714	63,620,529	149,132,116
1901	169,151	10,000		179,151	69,389,194	167,424,089
1902	295,209	36,540		331,749	88,766,916	181,965,876
1903	931,015	140,000		1,071,015	100,461,337	194,804,294
1904	4,236,336	1,366,700	65,455	5,668,491	117,080,960	218,299,419
1905	3,892,868	8,561,950	75,592	12,530,410	134,717,580	215,361,296
1906	3,075,571	18,618,583	111,072	21,805,226	126,493,936	214,010,124
1907	3,331,404	42,830,250	83,260	46,244,914	166,095,335	264,958,109
1908	2,473,107	45,801,675	85,963	48,360,745	178,527,355	285,101,456
1909	1,032,117	46,975,150	113,485	48,120,752	183,170,874	298,391,647
1910	1,129,313	52,300,000	126,531	53,555,844	209,557,248	327,636,356
1911	2,907,150	56,425,700	1,068,544	60,401,394	220,449,391	345,673,200
1912	2,182,042	51,425,430	4,424,525	58,031,997	222,935,044	352,446,598
1913	2,171,659	63,575,200	8,480,000	74,226,859	248,446,230	383,753,547
1914	3,850,000	97,242,263	8,850,000	109,942,263	265,762,535	398,698,366
1915	4,115,800	117,883,115	6,356,000	128,354,915	281,104,104	427,740,129
1916	11,530,487	111,141,280	8,275,140	130,946,907	300,767,158	461,493,226
1917	38,029,561	97,603,233	10,432,054	146,064,848	335,315,601	506,702,902
1918	43,253,470	84,950,291	15,000,000	143,203,761	355,917,716	536,000,000
1919 * (Estimated)	30,000,000	84,000,000	63,000,000	177,000,000	377,000,000	565,000,000
Total,	159,112,978	980,897,735	126,547,621	1,266,558,334	4,985,471,619	8,057,000,000

* The figures for Oklahoma, Kansas, and Texas differ somewhat from those listed in the annual reports on Production of Oil, published by the United States Geological Survey. The difference is due to the fact that those official figures are for oil marketed and not for oil produced: they do not include the large stocks of unmarketed oil which accumulate in field storage during some years, nor deduct those released for marketing in other years.

View No. 1. Great flow of oil from the Trapshooter Well, Eldorado Oilfield.

LIFE OF THE FIELDS

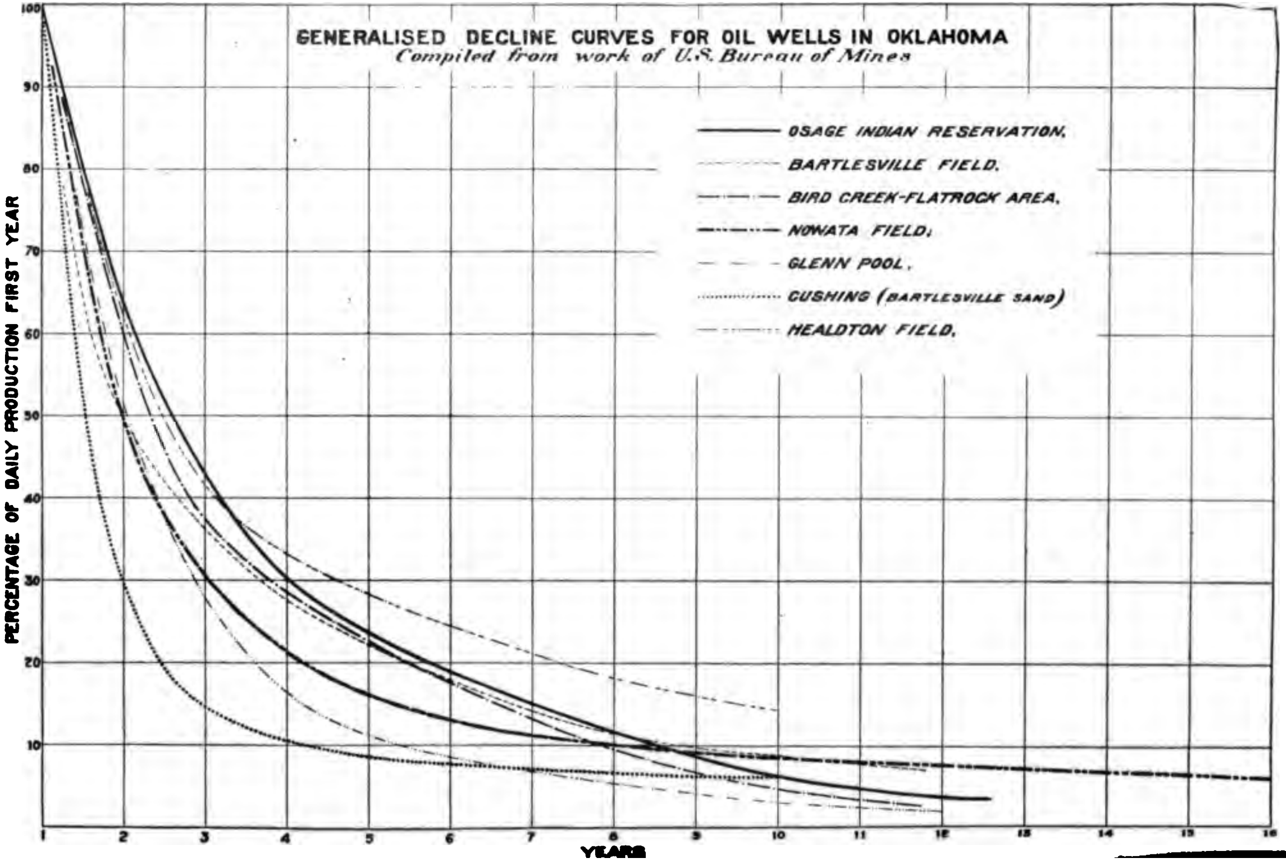
The oil wells in the Mid Continent field are only moderate producers. They are noted rather for their collective results than for individual merit. In the early shallow fields, both in Kansas and Oklahoma, there were wells which gave 1,000 barrels per day, but very few which attained to 2,000 barrels.

There are some larger wells, however, in the deeper fields, especially in the Cushing field, where some have yielded from 10,000 to 12,000 barrels a day. Also in the new fields of Ranger and Desdemona, in north-central Texas, many wells have "come in" at the rate of 5,000–12,000 barrels. The largest producers, however, were in the fields of Augusta and Eldorado, where a number of wells have had an initial yield of 10,000–20,000 barrels a day.

But generally, the average initial production per well for the region has been less than 100 barrels a day, and in some fields it has been below 50, and occasionally below 30. Under rapid development, such as has been general in these fields, an oil pool soon loses its vitality. After two or three years the wells newly drilled no longer are flowing wells, and their production is small compared to that of the early wells. For instance, in the Glen pool in the first year, 1906, the average initial production per well probably exceeded 400 barrels a day, and for the second year it exceeded 300, but in the fourth year the figure was only 78, and in the fifth year 62.6.

The great oilfields, such as Glen, Cushing, Healdton and Augusta-Eldorado, quickly attained their maximum output and then soon declined. The life of individual wells also is not long and there is a rapid fall from their initial yield. So far as is known no perceptible replenishment of the reservoirs occurs.

Fig. 4.


GENERALISED DECLINE CURVES FOR OIL WELLS IN OKLAHOMA
Compiled from work of U.S. Bureau of Mines
OSAGE INDIAN RESERVATION.
BARTLESVILLE FIELD.
BIRD CREEK-FLATROCK AREA.
NOWATA FIELD.
GLENN POOL.
CUSHING (BARTLESVILLE SAND)
HEALDTON FIELD.
PERCENTAGE OF DAILY PRODUCTION FIRST YEAR
100
90
80
70
60
50
40
30
20
10
YEARS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

AMOUNT OF DRILLING

The amount of drilling which has been done in the region is very large.

The year in which the greatest number of wells was drilled was 1918, the number being about 12,850, but in 1913 and 1914, 1916 and 1917, also, over 11,000 wells were drilled. The total number of wells drilled in the Mid Continent fields is about 120,000.

WELLS FINISHED IN EACH YEAR SINCE 1910

	1911	1912	1913	1914	1915	1916	1917	1918
Kansas	418	949	2016	2340	1088	3624	3495	3231
Oklahoma	4087	5993	8851	8292	4624	7583	6765	8367
North Texas	71	400	773	719	286	585	1003	1225
Arkansas	–	–	–	–	2	32	40	20
TOTAL—	4576	7342	11640	11351	6000	11824	11303	12843

Total number of wells drilled up to the end of 1918—about 110,000.

FUTURE NEW DEVELOPMENTS

From the foregoing outline of the field's history, it is seen that there has been continual progress from east to west and from north to south, whilst at the same time deeper and deeper drilling has come into practice. This deepening westward conforms to the geology, for throughout the region the strata have a general dip westward [30 feet—more or less—per mile]: consequently as we advance in that direction we must either look for production in higher beds or else we must drill to greater depths. As a rule the higher formations have proved less petroliferous than the lower formations which were originally exploited. Here and there new shallow fields are found, but eventually deeper wells are drilled in them in order to produce from the lower horizons.

Thus the oilman's face is set ever westward, with the prospecting outfits seeking new fields in front and the developing outfits drilling deeper in the proven field immediately behind.

Because of the scanty success in the higher formations, it has become usual in the last three years, when prospecting westward, to begin with the expectation of drilling to 3,500 feet. It is at such depths that a heavy production has been developed in the new fields in the north part of Oklahoma and in the new fields in north Texas which are now attracting so much attention.

Regarding the future it is not to be supposed that this great oil region is yet to decline. There is still considerable undrilled territory similar to that which is producing to-day. Also, extending westward there is a vast area underlain by the whole Pennsylvanian System at still greater depths; and we need not suppose that the limit of operative depth will stay at 3,000–4,000 feet now, any more than it stayed at 1,000–2,000 feet a few years ago.

Apart from this, in the wide expanse of the Permian, there are areas worthy to be prospected in search of production at higher horizons. The great wealth of oil in the Permian at Healdton demonstrates that although much of that system may be barren yet there are conditions which render it highly productive in some localities.

Likewise, in some districts, there is now the expectation of producing much oil from formations below the Pennsylvanian—for the new pools in northern Texas show that in that part of the region at any rate, the Bend Formation of the Mississippian is very rich. This formation extends over a very large area, and though it lies deep, the next few years will see it extensively exploited.

The deep drilling which has now become necessary in the Mid Continent Region makes failures very costly. Such aid as geology can give is being utilized on a large scale by the leading companies, and hundreds of skilled geologists are employed.

PART IV

GENERAL GEOLOGICAL STRUCTURE OF THE MID CONTINENT OILFIELD REGION

SECTION A

THE GEOLOGICAL SYSTEMS

The geological systems in the Prairie Plains Monocline are as follows. The thicknesses here stated apply to a great part of the region, but are not applicable in or around the uplift areas, where littoral conditions were frequent, and thicker deposits were formed.

	Cretaceous System (Marine)	1,300 ft.
	great unconformity.	
Petroleum	Upper Permian System (Continental)	1,200 ft.
	Lower Permian System (Marine)	1,100 ft.
	perfect conformity.	
	Pennsylvanian System (Marine)	3,000 ft.
	unconformity.	
	Mississippian System (Marine)	300 ft.
	unconformity.	
	Lower Palæozoic Systems (Marine)	2,000 ft.
	Archaen Rocks (Igneous and Metamorphic)	

The oil and gas occur mainly within the Pennsylvanian; but the Permian and the Mississippian also are productive in some districts.

SECTION B

GENERAL STRUCTURE OF THE REGION

The Pennsylvanian and Permian deposits of the Mid Continent Oilfields occur as a great mass of sediments, which appear horizontal to the eye. By survey, however, it is found that the whole pile is tilted westward in the form of a monocline (Prairie Plains Monocline), dipping at from 10 to 50 feet per mile, the average being 20 to 30 feet per mile.

Most of the oilfields are situated on the outcrop of the Pennsylvanian, which is about 100 to 150 miles, or more, in width, and has a length of nearly 700 miles; but some of the fields lie farther west, on the outcrop of the Permian (especially at the eastern edge of it) which also is 100 to 150 miles in width.

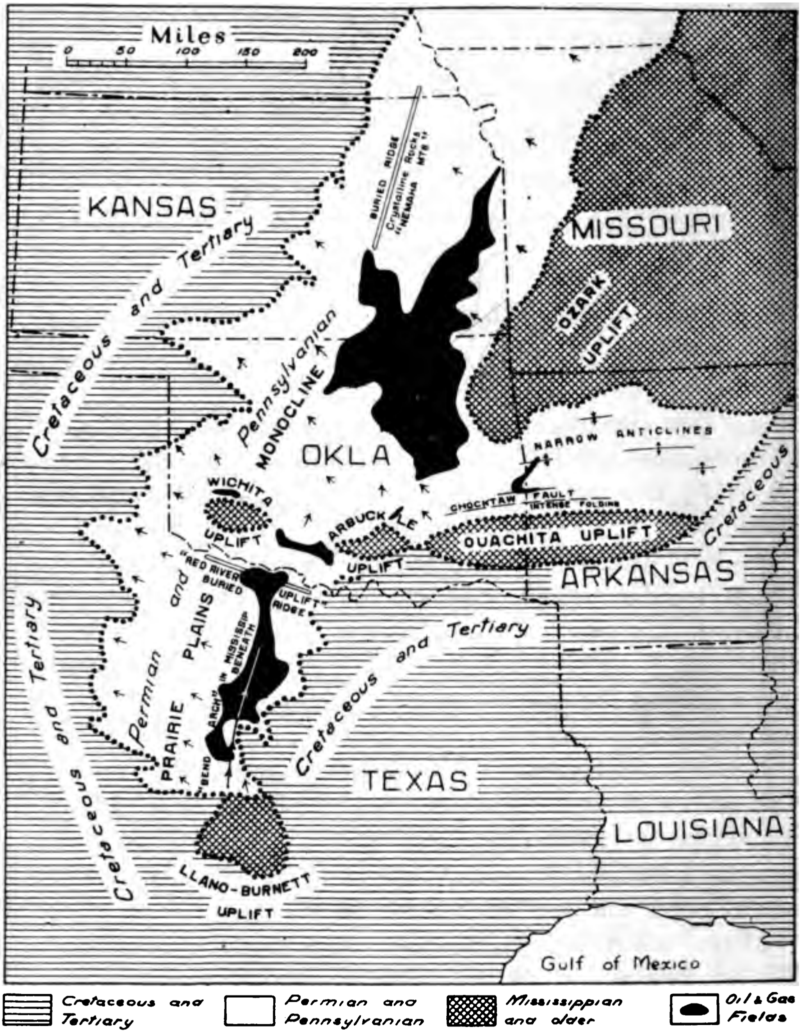
Before entering into details about the monocline, we must first notice several areas of older rocks, with which the monocline is structurally connected. Each of these has a general anticlinal structure, and they are usually referred to as "uplift masses," or "mountain uplifts."

These districts of upfolded older rocks,—the Ozark, Wichita, Arbuckle, Ouachita and Llano-Burnett uplifts,—are inside the Mid Continent Oilfield Region, or are at its margin, but there are no oilfields on them.

The movements which produced the uplifts were mainly

FIG. 5.

GENERAL STRUCTURE MID-CONTINENT REGION



pre-Pennsylvanian, but they continued during and after the Pennsylvanian and Permian, and the slight tilting of the Prairie Plains Monocline was a part of them.

The great monocline, which contains the oil-bearing rocks, occupies an extensive region in which the deposits have remained undisturbed to a remarkable degree. The Lower Palæozoic and Upper Palæozoic Systems, which cover the area, to this day lie almost as they were deposited. There are, however, many very slight folds; and it is on these that the oil-pools occur.

SECTION C

THE UPLIFT MASSES

Just adjacent to the uplift masses, the strike turns a little here and there, conforming to their outlines, but away from these uplifts, throughout most of the region, the monocline maintains a general north-northeast strike, with a westerly dip of about half a degree.

To westward these Permian and Pennsylvanian beds disappear under the Cretaceous escarpment, and they do not reappear until the foothills of the Rocky Mountains are reached. There they are sharply upturned in the Rocky Mountain folds.

As to the nature of the movement which caused the Prairie Plains Monocline, opinion would differ. By some it might be considered as a sagging down of a portion of earth crust—the several so-called "uplift areas" being "horsts," or more resistant blocks which did not sink. By others the monocline is regarded as merely the western limb of the Ozark anticline, with modifications due to the other uplifts. By others, again, it is considered as the eastern limb of a wide but gentle geo-synclinal, whose western limb is covered over by the Cretaceous of the West.

The Ozark Uplift

The Ozark uplift, which borders the oilfields on the east side, is the largest of these masses. It occupies the greater part of Missouri and a small area in the southeast corner of Kansas and the northeast corner of Oklahoma. The Ozark area was overlain by the Mississippian deposits, but had partly emerged from the sea before the Pennsylvanian beds were laid down. It now consists of a ring of Mississippian rocks, dipping outward in all directions and inclosing a core of Ordovician and older rocks. It separates the synclinal basin of the Western Interior Coal Field (Kansas and Oklahoma) from the Eastern Interior Coal Field (Illinois and Indiana).

The structure is not one simple arch, but contains complicated folds and faults. Contemporaneous denudation of the uplift probably contributed to the sediments laid down in the Pennsylvanian waters. The general anticlinal axis of this uplift has a N. N. E. direction. Pennsylvanian beds of the Prairie Plains Monocline, which were laid down in the sea to westward of the uplift, have their strike parallel with the margin of the Ozark mass, and doubtless their inclination is due to the continuance of the same movement in post-Pennsylvanian time.

The Wichita-Arbuckle-Ouachita Uplift

In southern Oklahoma there are three mountain uplift areas of similar origin. In order, from west to east, these are the Wichita, the Arbuckle and the Ouachita masses. They lie along an east and west line across the Mid Continent Oilfield Region, and have a general anticlinal structure about this axis. The folding is more complex than in the Ozark uplift. The Wichita mass and the Arbuckle mass comprise Lower Palæozoic, Pre-Cambrian and Igneous rocks. The Ouachita mass consists mainly of Mississippian deposits with a core of Lower Palæozoic rocks. These were upraised by movements which occurred chiefly at the close of the Mississippian and at the close of the Pennsylvanian periods, and which were continued to a less degree during and after the Permian. Denudation of these mountains provided a great quantity of sediment to the later Pennsylvanian and Permian deposits to north and west and south. The thickness of those systems is found to be much greater as the mountain masses are approached.

On either side of this line of uplifts in southern Oklahoma, the Pennsylvanian and Permian beds dip away from the axis. Thus, on the north side, there is a general dip to northward, and, on the south side, to southward. This attitude of the Pennsylvanian and Permian is only local, and at a distance from the uplift the inclination changes gradually into the normal western dip of the general monocline.

The outcrop of the Pennsylvanian is interrupted by these uplifts in southern Oklahoma, so that the outcrop to the south of them, in Texas, is separated from the outcrop to the northward. The Permian, however, overlaps the Pennsylvanian on to the older rocks, and its outcrop passes around the uplift and is continuous southward into Texas.

The Folded Area in S. E. Oklahoma

In the southeast of Oklahoma there is a special district wherein the structure of the Pennsylvanian differs from that in the main part of the region. This district is north of the Ouachita uplift, between it and the Ozark uplift. Here, not unnaturally, there has been more disturbance, and the strata are thrown into a number of comparatively sharp folds about axes having an E. N. E. direction. It is to be noted that no oilfields have been found in this area, though there are some small fields of gas.

The Llano-Burnett Uplift

In north Texas, at the extreme southern end of the Mid Continent Oilfield, the Llano-Burnett uplift reveals the older rocks again, in general anticlinal or dome-like form.

Here, again, the movement has continued in post-Pennsylvanian times, and the Pennsylvanian beds north of the uplift have a strike parallel to the margin of the uplift, and a dip towards the north.

The Nemaha Mountains

There are three other notable places within the region, in which there is some evidence of similar anticlinal or uplift movement.

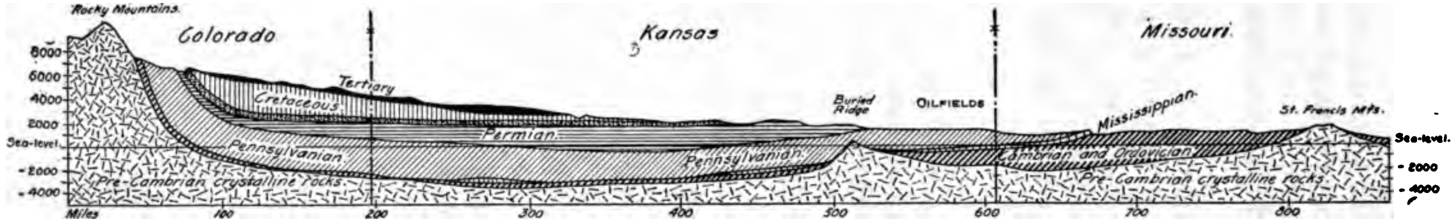
One of these is in the centre of Kansas, where a ridge of crystalline rocks approaches to within moderate depth from the surface. Here, these old rocks are directly overlain by Pennsylvanian beds, in which a belt of slight folding coincides with the trend of the buried ridge. (See Fig. 5 and Fig. 6.)

The ridge has been named by Professor Haworth the Nemaha Mountains. It has been proved by the drill for a length of 165 miles, from the north of Butler County (10 miles north of the Eldorado Oilfield), where it was met at 2,500 feet, away northeastward into Nebraska, where it is within 550 feet of the surface.

Probably these Nemaha Mountains are an uplift mass closely related to those described above.

The Bend Arch

In northern Texas the drilling seems to have proved the presence, at depth, of a general anticlinal in the Mississippian rocks, with an axis trending northward from the Llano-



Section across North end of Mid-Continent Oil Region from Ozark Uplift to Rocky Mountains.

FIG. 6.

(After Moore and Haynes, Bull. 3, Geol. Surv. of Kansas.)

Burnett uplift toward the Oklahoma border (see Part VI). This structure is completely concealed under the monocline of overlying Pennsylvanian beds; but in them a belt of minor structures coincides with the direction of the axis of the fold.

Much surveying is in progress, of which the full results are not available, but, if this structure in the Mississippian is definitely proved, it appears likely that the Pennsylvanian beds above it, also, will have been affected by at least some slight continuance of the movement.

The Red River Uplift *

Along the north border of Texas, completely concealed by the overlying Permian deposits, there is another uplift-mass of older rocks, apparently of similar character to those already described.

Here, in various places, limestones of Ordovician age have been found at depths of from 1600 to 2400 feet; and "granite" was encountered at 4240 feet. Southward of these holes, a limestone thought to be the Bend Limestone, was struck at 3970 feet.

The facts established at present are scanty but it is inferred that the Red River Uplift has a W. N. W. trend, parallel with the Wichita Arbuckle Uplift. The line of it is immediately south of the river, passing through the north part of Wichita County and Clay County. The uplift was of pre-Pennsylvanian age; and the Pennsylvanian deposits lie unconformably on or against it.

The minor folding, which is perceptible in the Pennsylvanian and Permian beds, occurred along the old line of movement and has been determined by it. Thus the oilfields of Wichita and Clay County (Electra-Burkburnett and Petrolia fields) are situated near or over this uplift.

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* See article by Lee Hager, Oil and Gas Journal, Oct. 17, 1919.

SECTION D

THE MINOR STRUCTURES ON THE MONOCLINE

In the foregoing description we have spoken of a general monoclinal structure, a general strike and a general dip. By detailed survey work, however, it is found that the monocline is not perfectly plane, but is wrinkled irregularly with very slight undulations, more or less parallel to the line of strike, and also sometimes with irregular corrugations along the direction of dip. The dip of the rocks on either flank of the undulations rarely exceeds 1 or 2 degrees, and so these anticlines are not easily perceived. Often, indeed, this dip is not sufficient on the east side of the structure to neutralize the general dip to westward pertaining to the monocline, and thus the flexure does not amount to an anticline at all, but may be called a "terrace."

It is on these anticlines, domes and terraces that the accumulations of oil occur. The structures occupy areas of varying size, from a few hundred acres up to several hundred square miles. Some may be 5 or 10 miles wide and 10 or 20 miles in length, whilst others are less than a mile across and die out at their ends in a length of 2 or 3 miles. The outlines are not regular, though they tend to the elliptical form. (The minor structures are more fully discussed in Part VII.)

The slight movements which produced and wrinkled the Prairie Plains Monocline, and the movements which caused the several uplift masses, were of Permo-Carboniferous age. They belong to the great system of earth movements which raised the Appalachian Mountains of America and the "Palæozoic Alps" of Europe.

PART V

GEOLOGICAL HISTORY OF THE OIL-BEARING DEPOSITS

The geological history of the Mid Continent Oil Region appears fairly simple.

The Mississippian, Pennsylvanian and Permian strata were deposited near the eastern shores of an ancient Pacific Ocean. This shore stretched across the present American Continent, from the Yukon to Florida, in a line which was nearly straight, except for a large bay extending northeastward across Missouri, Illinois, etc., as far as New York State.

During these periods, there was gradual recession of the sea, and elevation of some particular parts of the land.

These particular districts of elevation are the uplift-areas referred to in the previous chapter as the Ozark, the Ouachita, the Arbuckle, the Wichita, and the Llano-Burnett uplifts,—which are now marked by higher ground in which Archæan and Lower Palæozoic rocks are exposed.

In the Mississippian Period, there was a fairly deep sea, in which some 300 feet or more of massive limestones were laid down over the greater part of the region.

The uplift movements commenced to some extent within this period (or possibly earlier in some cases), and islands were produced, or peninsulas, projecting westward from the mainland into the Mississippian sea.

At the close of this period, the Ozark mass was probably represented by an island—but the thick Mississippian limestones in southeast Kansas and northeast Oklahoma indicate that the main uplifting, immediately east of them, did not occur until after they had been laid down.

The Ouachita, Arbuckle and Wichita uplifts, which lie along one east and west axis in southern Oklahoma, also were partially upraised before or during the Mississippian Period. The thick littoral development of the Mississippian in the Ouachita district testifies to the presence of land hard by.

At the close of the period, the movements in the uplift areas became more pronounced, and the adjacent deposits of the Mississippian sea were affected by them.

But, away from the uplifts, the movements were extremely slight, and the deposits remained practically horizontal. In north Texas, however, there was sufficient movement to make a gentle, but extensive, anticlinal fold, which has now been revealed by the drilling of deep wells.

After the Mississippian deposits had been formed, there was also some recession of the sea from its eastern shore; and there was an interval of time in which some sub-aërial erosion took place,—for at the base of the Pennsylvanian, a well-marked unconformity is found. It is not known how far west of the uplifts the unconformity exists—but in all exposures, and in many wells in the east part of the oilfields, it is evident that the lowest beds of the Pennsylvanian rest on an irregular floor.

The buried ridge in north central Kansas,—the Nemaha Mountains,—also probably were upraised at the close of the Mississippian or earlier, and underwent erosion in the interval before the Pennsylvanian. At any rate, the Pennsylvanian beds rest unconformably on the crystalline rocks of this concealed ridge.

At the commencement of the Pennsylvanian period, the waters returned as far as the edge of the uplift masses, and probably covered parts of them.

The eastern gulf was now divided up into more or less isolated seas, or arms of the sea, and the waters of Kansas and Oklahoma were separate from those of Missouri.

Thus, in Pennsylvanian times the shore-line extended from north to south, along the eastern border of Kansas and Oklahoma, and southward into Texas, whilst in the south part of Oklahoma, there was an island, or group of islands, trending eastward and westward along the line of the Wichita-Arbuckle uplift.

The Pennsylvanian sea was shallow, and the land was fringed by swamps and lagoons. The continuance of the movements had produced many irregularities.

The elevation of the uplift-masses continued, and was accompanied by gradual subsidence of the sea floor. The denudation of the newly-raised lands caused rapid accumulation of sediments.

The water became alternately deeper and shallower, and instead of massive limestones, such as were formed in the Mississippian sea, we have now alternations of shale and sandstones, thin limestones and coals. In Kansas, some 3,500 feet of Pennsylvanian and Permian deposits were thus produced, thickening southward to 5,000 feet in Oklahoma and Texas; and to 15,000 feet of shallow water deposits in southwest Oklahoma, along the Ouachita shore-line.

Thus, the uplift movements of the land, and subsidence movements of the sea-floor, together with the silting up, had resulted in unstable and rapidly alternating conditions of deposition.

This is a frequent combination of circumstances in geological history; and deposits formed under such conditions are precisely those in which the world's great stores of petroleum are found.

The principal uplifting of the land masses took place during, or at the close of, the Pennsylvanian and Lower Permian period.

The Ozark uplift, which had been an island during the Mississippian, had grown during Pennsylvanian time into a large barrier separating the Pennsylvanian deposits of the Mid Continent Field from those of Missouri.

Likewise, in southern Oklahoma, the Wichita, Arbuckle, and Ouachita masses became a barrier partially separating the Pennsylvanian deposits of Oklahoma from those of north Texas.

In the Permian period, the contraction of the sea progressed rapidly, and the waters gradually became more or less land-locked remnants, in which red clays and sandstones, with seams of salt and gypsum and dolomite, were laid down.

In southern Oklahoma, and north Texas, around the gradually rising uplifts, these continental conditions came into existence at the commencement of the Permian time,—but in Kansas and northern Oklahoma, the marine conditions lingered on until about halfway through the period.

Thus, in Kansas and northern Oklahoma, we have some 1,000 feet of marine Permian deposits, succeeded by 1,200 feet or more of red rocks of continental type; whilst in southern Oklahoma and north Texas, the whole of the Permian is represented by red beds, 1,000 to 2,000 feet thick.

During the Permian period, the uplift-masses were much reduced by denudation. Partly on account of erosion and partly due to some subsidence, the Wichita and Arbuckle uplifts were overlaid by the red Permian beds. Subsequently the uplifting movement was resumed, and the Permian deposits surrounding these mountains now have the form of a gentle arch.

Thus, throughout all the Mississippian, Pennsylvanian, and Permian periods, the movements were more or less continuous, and the uplift-masses were repeatedly more and more upraised.

But away from the uplifts, throughout most of the Mid Continent Oilfields Region, the movements have been remarkably slight, so small, indeed, that the deposits appear to the eye to have retained their original horizontal position. In fact, the Mississippian, Pennsylvanian and Permian deposits of the Mid Continent Region constitute one of the most undisturbed masses of Palæozoic strata in the world.

Although the movements by which the Prairie Plains Monocline has been affected are so slight, their results are very important, for it is the minor wrinkles, anticlines and terraces on the monocline, which are now the sites of the great pools of oil.

After the close of the Permian period, continental deposition continued through the Triassic time; and the sea did not return until the period of the Cretaceous; when it invaded the western and southern part of the region.

In the Tertiary period the sea withdrew from the region during the Eocene, but advanced into western Oklahoma and Kansas during the Miocene, after which it gradually withdrew to its present place (the Pacific Ocean).

The latest incident of interest was the Glaciation of North America; but the ice sheet reached only to the northeast corner of Kansas, and did not invade the oilfields.

PART VI

THE STRATIGRAPHY AND THE OILFIELDS

CHAPTER I

SYSTEMS OF FORMATIONS IN THE REGION

In previous pages (Part IV and V), a general outline of the geology has been stated. The present Part will deal with the actual deposits, and with the oilfields wherein they are exploited.

Each of the main Geological Systems will be discussed in order, beginning with the oldest, and will be reviewed from north to south. After the discussion of each System, a brief account will be given of the principal oilfields which produce from it.

The following table shows the geological systems present in the Prairie Plains Monocline. The thicknesses are only approximate, and they are not applicable in or around the uplift areas, where littoral conditions caused thicker deposits to be formed.

Cretaceous System (Marine)		1,300 ft.
Great Unconformity		
Upper Permian System (Continental)	Oil-bearing	1,200 ft.
Lower Permian System (Marine)		1,100 ft.
Perfect Conformity		
Pennsylvanian System (Marine)		3,000 ft.
Unconformity.		
Mississippian System (Marine)		300 ft.
Unconformity		
Lower Palæozoic Systems (Marine)		2,000 ft.
Unconformity		
Archæan Rocks (Igneous and Metamorphic).		

The oil and gas occur mainly within the Pennsylvanian: but the Permian and the Mississippian also are productive in some districts.

The systems will now be briefly considered, starting from the base, as it is important to have in mind all that is underneath the oil.

CHAPTER II

THE ARCHEAN ROCKS

The Archean rocks, consisting of Gneisses and Schists with Igneous intrusions, are exposed at the surface in several of the uplift mountain areas, namely, the Arbuckle and Wichita mountain masses, in the south of Oklahoma; and the Llano-Burnett uplift of north central Texas. To eastward of the region, they are exposed in the St. Frances Mountain of southeast Missouri, which is a part of the Ozark uplift; and to westward, they outcrop in the Rocky Mountains.

Away from the uplifts, the Archean rocks underlying the region, are generally at depths of 2,000–5,000 feet. In eastern Kansas, they have been reached at about 2,000 feet in several wells. Passing westward, the depth gradually increases to 5,000 feet, or more. In central Kansas, however, they approach nearer to the surface again in the form of a steep ridge, which lies buried under the Pennsylvanian beds. (Nemaha Mountains, referred to in Chapter IV.)

In Oklahoma, at a distance from the uplifts, the Archean rocks lie deeper than in Kansas, and all the overlying formations have greater thickness. In parts of southern Oklahoma and north Texas where the Lower Palæozoic and Pennsylvanian are very thick, the depth to the Archæan floor must be 5,000–8,000 feet.

CHAPTER III

THE LOWER PALAEOZOIC SYSTEMS

Beneath the Permian, Pennsylvanian and Mississippian systems, which contain the petroleum, there is a layer of Lower Palæozoic deposits, which is spread over practically the whole region, resting on a floor of Archean rocks. In the oilfields, they lie almost horizontal, and have been penetrated by many wells.

These beds are exposed at the surface in the five uplift-mountain areas of the Mid Continent Oil Region, where they are sharply upturned and outcrop in more or less concentric belts, dipping away from a central area of Archean rocks. In these uplift districts, representatives of each of the Lower Palæozoic systems are found, but it is only the Cambrian and Ordovician which have wide and continuous extent.

The Lower Palæozoic beds, underlying most of Kansas, as proved by the drill, appear to consist of some 2,000 feet, or more, of Cambrian and Ordovician dolomites and sandstones and shales, which probably thin out considerably to westward. In the center of Kansas, their continuity is interrupted by the buried Archean ridge. Along the crest of this buried ridge the Lower Palæozoic deposits are absent, and the crystalline rocks are overlain directly by Pennsylvanian beds. There is a tendency for gentle anticlinal structures in the Pennsylvanian to occur along the line of the ridge, but no productive field has been developed in them, overlying that portion of the ridge which is definitely known. Along the same line, continued southward, however, are the great oilfields of Augusta-Eldorado and Kay County.

The exposed Lower Palæozoic rocks in northeast Oklahoma, bordering the Ozark uplift, include the Bergen Sandstone, 100 feet thick, and the Tyner Shales, 100 feet, both of Ordovician age; and the Sinclair Marble, over 200 feet thick, which is of Silurian age; and the Chattanooga Shale, 100 feet thick, which probably is Devonian. Below all these, there is doubtless a considerable thickness of Cambrian beds.

The Lower Palæozoic rocks exposed in southeast Oklahoma in the Ouachita mountain district, consist of some 12,000 feet of shales and sandstone, belonging to the Ordovician and Silurian systems. This great thickness is only local, and it is not supposed that such deposits extend so far northward as to be present under the main oilfields.

The exposed Lower Palæozoic of the Arbuckle and Wichita mountain uplifts of south Oklahoma have a thickness of 10,000 feet, or more, being chiefly limestones and shale, of Cambrian and Ordovician age. The principal members are the Arbuckle Limestone, 5,000 feet thick; and the Simpson formation, mainly sandstone, 1,500 feet thick; both belonging to the Ordovician system.

Some tarry seepages occur in the neighborhood of the Wichita Mountains, in sandy beds belonging to this limestone series; and in the surrounding country, such wells as have been drilled through the Permian into this limestone, have encountered showings of oil therein. In the Arbuckle Mountains, sandstone, impregnated with asphaltum, is exposed in the Simpson formation.

The Lower Palæozoic beds, exposed in the Llano-Burnett uplift area of Texas, have a thickness of 1,350 feet, the principal member being the Ellenberger limestone, 1,000 feet thick, which is of Ordovician and Cambrian age. This limestone was reached by a deep well at Ranger at 3,603 feet and was penetrated to 3,709 feet.

CHAPTER IV

THE MISSISSIPPIAN SYSTEM

SECTION A

GENERAL CHARACTER OF THE MISSISSIPPIAN

The Mississippian contains the lowest of the oil-rocks which contribute to the production of the Mid Continent Region. It is only in the past two years, with the opening of the new fields in north Texas, that this contribution has grown to an important size, though previously, in northeast Oklahoma, gas and a small amount of oil were being obtained from some beds of Mississippian age.

The Mississippian deposits are exposed at the surface only around the several uplift areas to which reference already has been made. In order from northeast to southwest, these are the Ozark uplift of southeast Kansas and northeast Oklahoma, the Ouachita, Arbuckle, and Wichita uplifts of southern Oklahoma and the Llano-Burnett uplift of Texas.

Around these masses, the outcrop of the Mississippian has more or less the form of an irregular ring surrounding the Lower Palæozoic rocks and dipping away from the center.

Elsewhere in the region, these deposits are not exposed, though in many places they are reached by the drill.

Traced away from the neighborhood of the uplifts where they are exposed, into the oilfields where they are not exposed, the Mississippian deposits change to some extent. This applies especially to southern Oklahoma, where thick littoral deposits were formed around the uplifts. These shallow-water beds pass gradually into the normal deeper water limestones at a distance from the uplift-areas.

Throughout the Mid Continent Fields, the Mississippian is mainly a limestone deposit, corresponding to the Carboniferous Limestone of Britain and Europe. It occurs as a fairly uniform layer, 300–400 feet thick, inclined towards the northwest, west, or southwest, at about 10 to 20 feet per mile.

The Mississippian deposits will now be briefly noticed in order from north to south.

SECTION B

THE MISSISSIPPIAN IN KANSAS

In Kansas, the Mississippian has been proved as far west as the Augusta and Eldorado oilfields in the middle of the State, where it has been reached at a depth of 3,110 feet. West of this, we have no evidence until arriving at the front ranges of the Rockies where the Mississippian beds are upturned and crop out at the surface.

Under the oilfields of Kansas, the Mississippian consists mainly of massive limestone 100–350 feet thick, containing brachipods, corals, crinoids, etc. There is much chert in the limestone and the rock is very hard. To the drillers it is known as the Mississippi lime or the Boone Chert.

In the early fields of eastern Kansas and northeast Oklahoma, this limestone was found to be barren of oil, a large number of holes having been drilled into it and right through it without success.

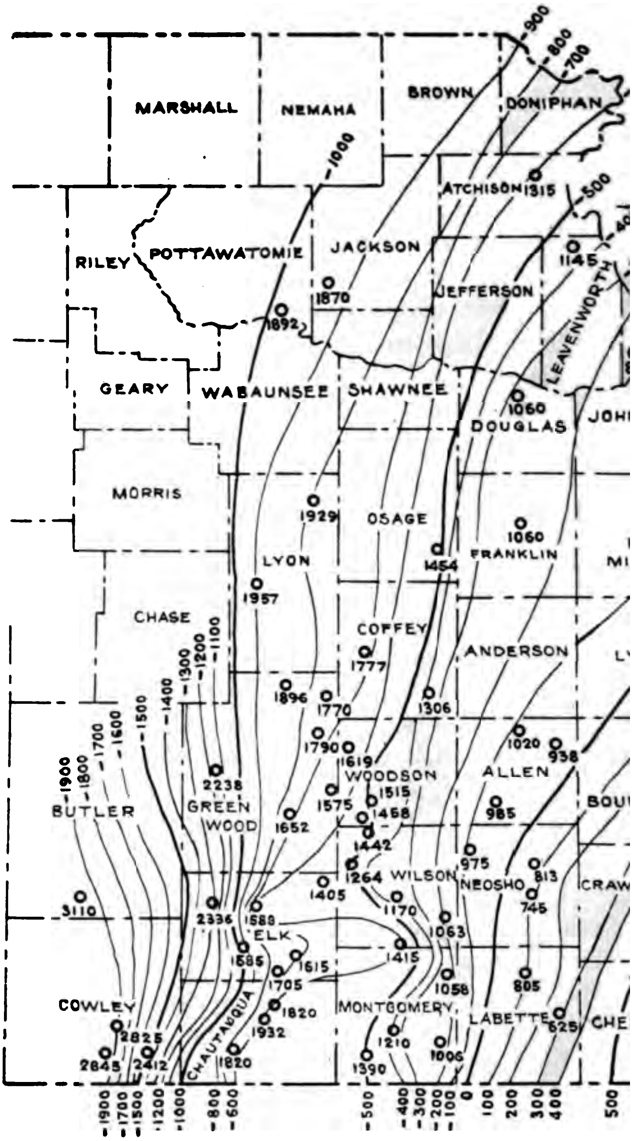

FIG. 7.

EASTERN KANSAS

STRUCTURE CONTOURS

on surface of

MISSISSIPPIAN LIMEST.

Contours indicate elevation in feet relative to sea level.

Many deep wells shown with depth of Mississippian below surface

Scale in Miles
0 10 20 30 40 50

(From Kansas Geological Survey)

The general structure of the Mississippian, underlying Kansas, has been worked out from the drilling records and is well expressed on a map in the excellent Bulletin No. 3, of the Kansas Geological Survey. By structure contours, of 100 ft. interval, this map shows the form of the surface of the Mississippian Limestone underneath the Pennsylvanian deposits. It is seen that the surface has a general inclination to W. N. W. or to W., at from 10 to 50 feet per mile. (See Fig. 7.)

The surface is not plain, though it is fairly smooth. When considered in finer detail, however, many irregularities are found due to the erosion which occurred before the Pennsylvanian deposits were laid over it.

These irregularities in the elevation of the surface, have been proved to be sometimes as much as 50 or 100 feet in half a mile, and occasionally exposures show the Pennsylvanian beds lying in hollows on the surface of the limestone. In some cases, thick coal occupies these hollows.

SECTION C

THE MISSISSIPPIAN IN NORTHEAST OKLAHOMA

In northeast Oklahoma, the Boone Chert is seen to have a thickness of 350 feet. This decreases gradually to 100 feet, as we pass southward to about halfway across the State. In this northeast part of Oklahoma, there are additional members at the top of the Mississippian, known as the Chester Group—and the Pennsylvanian also has an extra series at its base. Thus the sequence exposed east of the famous Glen oilfield is:

Lower part of Pennsylvanian System	Cherokee Formation	1,000
	(Unconformity)	
	Morrow Formation	110
	(Unconformity)	
Mississippian System	Chester Group	
	Pitkin Limestone (Blue and brown limestones)	60
	Fayetteville Series (Black shales, thin sandstones and limestones) (Thickens to 275 ft. at Glenfield)	40
	Mayes Series	15
	(Unconformity)	
	Boone Limestone	200

The general structure of the Mississippian underlying Oklahoma, inferred from drilling records, etc., is shown on the accompanying plan (Fig. No. 8) which is taken from a sketch map by J. H. Gardner published in the "Oil and Gas Journal." The structure contours (1,000 ft. intervals) are drawn on the surface of the "Mississippi Lime." It is seen that throughout the north half of Oklahoma the surface of the Mississippi Lime is inclined towards the southwest at 5,000–10,000 feet per 100 miles. Further southward it rises again, as the Wichita-Arbuckle line of uplift is approached.

In the earlier fields, though some yield of gas was obtained in the Mississippian, very little oil was found in that formation. A small production was obtained however, in those districts where the Fayetteville Series is present, chiefly in a sandstone known as the Mounds Sand.

But more recently the Mississippian has been found productive in a number of districts further westward and southward; notably in the Osage County fields; in the Yale field of Payne County; and in the Beggs district of Okmulgee County. During 1919 the output from the Mississippian has become important.

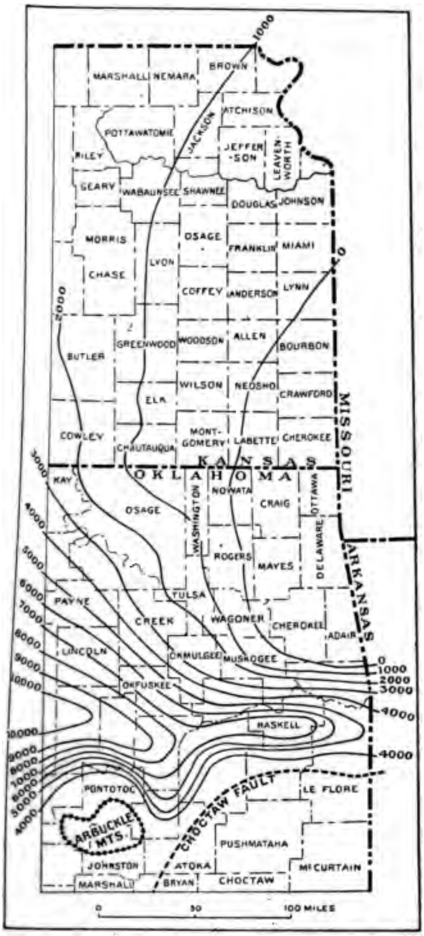

FIG. 8.

STRUCTURE CONTOURS

ON THE

MISSISSIPPI LIME

(KANSAS AND OKLAHOMA)

Elevations relative to sea level

Depths below surface can be obtained by adding surface elevations

(After Sketch Map in Oil and Gas Journal by J. H. Gardner.)

The oil occurs in the 'breaks' and sandy seams in the 'Mississippi Lime.' This cherty limestone series, 300–450 feet thick, which is reached after passing through the Cherokee Shales, is almost certainly the same as the Boone Chert or Boone Limestone, so well known further east and north.

OILFIELDS OF OKLAHOMA PRODUCING FROM THE MISSISSIPPIAN

The following notes, in small type, relating to individual oilfields are gathered from many sources. The more recent items are from the various oil journals.

Hominy Oilfield, Etc. (Osage County)

In Osage county, though most of the output is from the Pennsylvanian, several of the oilfields are now producing also from the Mississippi Lime, which is entered at various depths down to 2,500 feet or more.

In most of these cases the wells are rather small producers, making 5–50 barrels a day.

In the Hominy field however, there are now wells giving several hundred barrels a day, from horizons 5–300 feet down in the limestone.

Yale-Quay Oilfield (Payne County)

In the Yale field, which became an important producer in 1917–1918, the oil has been obtained chiefly from the Pennsylvanian, at depths of 2,700–3,300 feet.

Production from the Mississippian is being developed during the present year, 1919.

The top of the lime lies at 3,400 feet, and wells making 100–800 barrels a day, have been brought in at 3,500 feet.

Beggs Oilfield, Etc. (Okmulgee County)

The Beggs district has been a field of great activity during the past few years, and there is a large production from the Pennsylvanian, from sands at 1,700–2,600 feet.

During 1919, deeper drilling has proved the Mississippi Lime to be highly productive. Many wells have been brought in at 1,000–2,000 barrels a day, at a depth of 2,700–2,800 feet.

SECTION D

THE MISSISSIPPIAN IN SOUTHEAST AND SOUTHERN OKLAHOMA

Much less is known in southeastern and southern Oklahoma about the Mississippian under the oilfields. This is partly because the deposits exposed around the uplift districts are of a more littoral facies and partly because the oil production is in the Permian, and there is little information about the Mississippian to be obtained from the wells.

In the Ouachita mountain-uplift of southeast Oklahoma the Mississippian is not recognized, and it appears that the Pennsylvanian is resting directly on the Lower Palæozoic rocks.

But in the Arbuckle uplift region, further west in southern Oklahoma, some 1,800 feet of Mississippian sediments are seen. These consist of the Sycamore Limestone, 0–200 feet thick, overlain by 1,600 feet of black carbonaceous shale known as the Caney Shales. It is probable that this thick facies of the Mississippian passes gradually into the thinner limestone facies, as we leave the vicinity of the uplift region.

Still further west, in the Wichita uplift, the Mississippian is not exposed—being overlapped by the Permian Red Beds.

SECTION E

THE MISSISSIPPIAN IN NORTH TEXAS

In north Texas, the Mississippian is represented by the Bend Series, 900–1,000 feet thick, which is found outcropping around the Llano-Burnett uplift. Although this series rests directly on Devonian and Ordovician strata, it appears from the fossils, to be equivalent to the Chester Group rather than to the Boone Chert; and by some geologists it is regarded as Pennsylvanian. The Bend Series consist of:

Smithwick Shales dark, black carbonaceous shale	200–550 feet.
Marble Falls Limestone black, dark blue or gray limestone	200–500 feet.
Lower Bend Shales black fissile, bituminous shale with some limestone seams.	50–200 feet.

Some 70 miles north of the outcrop, at Ranger, the thickness of the Bend Series appears to be about 1,000 feet. In the "Dean" well the following thicknesses were found:

0– 905	Canyon Formation	Pennsylvanian.
905–2,620	Strawn Formation	Pennsylvanian.
2,620–3,178	Smithwick Shale	Bend (Mississippian)
3,178–3,603	Marble Falls Limestone	Bend (Mississippian)
3,603–3,709	Ellenberger Limestone	Cambro-Ordovician.

The Mississippian of north Texas, unlike that of Kansas and Oklahoma, is now proving to be a great source of oil. Seepages of tar at the outcrop of the Marble Falls limestone were well known years ago and were once used for axle grease. But until recently the petroleum accumulations remained undiscovered, owing to the great depth at which they lie. During 1917 and 1918, however, prolific pools have been opened up, and deep drilling to the Bend Series is now in progress over thousands of square miles of territory. The oil is found chiefly in sandy streaks in the Marble Falls Limestone, which is called by the drillers "The Black Lime." There is also considerable production from horizons in the Smithwick Shales.

The oil obtained from the wells is of green color and has specific gravity .84.

As this Bend Series is so rich in petroleum, it is worth while to notice its character, as observed at the outcrops at the north edge of the Llano-Burnett uplift. The details are as follows:

Smithwick Shales[*]—Thickness 400 feet.
Soft dark to black, carbonaceous shale with sandstone lenticles.
Marble Falls Limestone[†]—Thickness 350–450 feet.
(Type section at Marble Falls)

Black shales, thin bedded,	20 feet.
Limestones, dark gray, fine grained,	15 feet.
Limestones, black, massive, thin bedded,	30 feet.
Limestones, subscrystalline to crystalline, brownish gray,	30 feet.
Thin bedded dark gray or black, fossiliferous limestone, with productus,	4 feet.
Limestone, gray, crystalline, fine grained,	4 feet.
Limestone, gray with molluscan fauna, fine grained,	20 feet.
Limestone, black or dark gray, dense,	2 feet.
Light and dark gray, mottled limestone, with chert nodules,	5 feet.
Mottled gray limestone with crinoid stems 26 inches long,	5 feet.
Limestone conglomerate,	1 foot.

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[*] Bull. 44, University of Texas.

[†] Prof. Paper 71, U. S. Geol. Survey.

Limestone, gray, without chert,	2 feet.
Gray cherty limestone,	8 feet.
Limestone, black with cherty layers,	8 feet.
Black, evenly bedded limestone, with cherty layers,	9 feet.
Massive, gray, crystalline limestone,	8 feet.
Gray, cherty limestone,	25 feet.
Limestone, gray crystalline,	6 feet.
Fault,	
Limestone, gray, irregular bedded,	17 feet.
Limestone, with chert layers and lenses, black shaly,	22 feet.
Limestone with crinoid stems, gray massive,	60 feet.
Fault,	
Limestone, dark cherty,	7 feet.
Dove colored limestone with black bands and lenses	40 feet.
Conglomerate.	20 feet.
	368 feet.

Lower Bend Shale *—Thickness 50 feet.

Black fissile shale of uniform texture, evenly bedded and highly bituminous. It contains some layers of dark limestone. The Lower Bend Shales rest upon Lower Palæozoic Rocks.

The producing horizons in the Bend Series were stated (some months ago) to be as follows:

a. Smithwick Shale.
b. Contact of Smithwick Shale with Marble Falls Limestone.
c. Duke Sand, in the Marble Falls Limestone.
d. Gordon Sand, in the Marble Falls Limestone.
e. Jones Sand, in the Marble Falls Limestone.
f. Veale Sand, in the Marble Falls Limestone.

* Bull. 44, University of Texas.

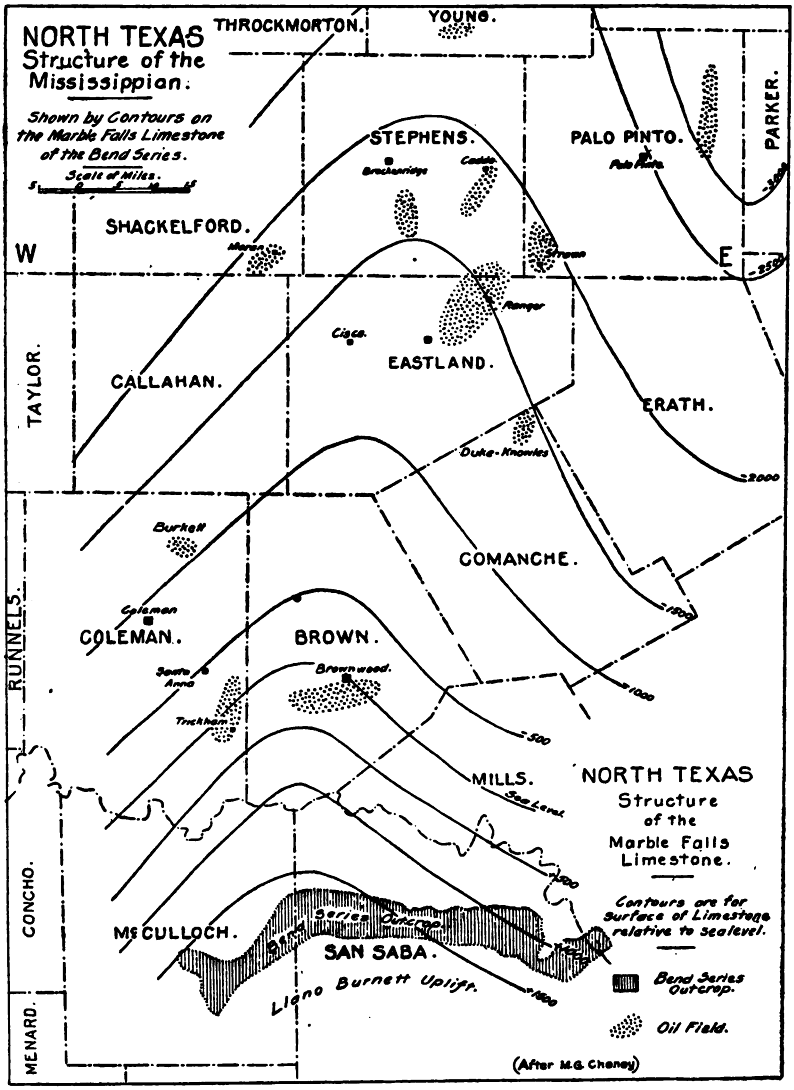
The chief fields producing from the Bend Series are:

Field	*County*	*Oil-horizon*	*Depth*
Ranger	Eastland	At 200 feet down in the limestone	3,420
Breckenridge	Stevens	At 30–100 feet down in the limestone	3,200–3,300
Caddo	Stevens	In part of the limestone	3,150
Coleman	Coleman	In black shales, 200 feet below the limestone (?)	3,400
		In black shales above the limestone (Smithwick Shales)	2,400
Gray	Coleman	In black shales above the limestone (Smithwick Shales)	2,400
Santa Anna	Coleman	In black shales above the limestone (Smithwick Shales)	
Trickham	Coleman	In black shales above the limestone (Smithwick Shales)	1,000–1,200
Desdemona	Comanche	In the limestone	2,700–2,750

Data derived from the drilling, show that the unconformity between the Mississippian and the Pennsylvanian is more pronounced here than in the Kansas part of the region, and there is in the Mississippian some important structure which appears to be independent of that in the Pennsylvanian.

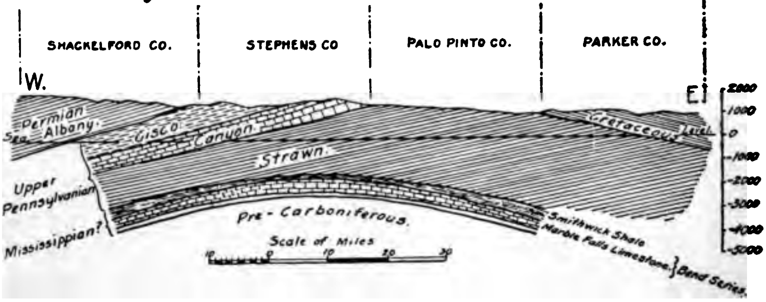
On the accompanying map, Fig. 9 (founded on work by Messrs. M. G. Cheney and Lee Hagar), this structure is shown by contours, at 500 feet intervals, indicating approximately the form of the surface of the Marble Falls Limestone relative to sea-level. From this it appears that the Mississippian lies in the form of a very broad, gentle anticline, which is

FIG. 9.



(After M.G. Cheney)

Geological Section across North Central Texas.



buried under the monocline of Pennsylvanian deposits. The axis of the fold extends northward from the Llano-Burnett region through north Texas, pitching down gently towards the north at about 30 feet per mile. The dip on either limb of the fold is about 50 feet per mile. The surface of the Bend Series, at the north edge of the Llano-Burnett uplift, would have an elevation of 2,000 feet above sea-level. Passing northward, and also northwestward and northeastward this surface sinks continually deeper, so that towards the Oklahoma boundary line it lies 4,000 feet, or more, below sea-level, and is covered by 5,000–6,000 feet of Pennsylvanian and Permian beds. (See also p. 36.)

It is stated that this general anticlinal structure does not occur in the overlying Pennsylvanian deposits, and evidently was produced almost wholly in pre-Pennsylvanian times. The folding presumably was a part of the same system of movements that gave rise to the several uplift masses which already have been enumerated.

On the overlying monocline of Pennsylvanian and Permian beds there are many small plunging anticlines, domes and terraces. It is not fully known to what extent these structures are impressed upon the Mississippian beds beneath,—but practically every one of the oilfields yet found in north Texas—whether producing from the Pennsylvanian or from the Bend—is located on one of those small folds.

Many geologists, skilled in mapping structure, are studying this territory and much more is known to them than has been made public. It is stated that 50–100 folds, large enough to have prospective value, already have been proved. (See Part VII, Chap. 19.)

OILFIELDS OF NORTH TEXAS PRODUCING FROM THE MISSISSIPPIAN

The following notes, in small type, relating to individual oilfields, are gathered frem various sources. The more recent items are from the oil journals.

Trickham, Coleman, Gray, Santa Anna Oilfields (Coleman Co.)

The Coleman County fields are near the south end of the Mid Continent Oil Region, situated on Pennsylvanian rocks.

At Coleman the oil was found at 3,400 feet, in black shales said to be at 200 feet below the "Black Lime" and supposed to be the Lower Bend Shales.

In the Gray district the oil is at 2,400 feet, in black shale considered to be the Smithwick shales.

At Santa Anna the depth of the wells is 1,560 feet and the oil is in black shale taken to be the Smithwick Shales.

In the Trickham district the depth to the oil is 1,000–1,200 feet and the productive beds are supposed to be the Smithwick Shales.

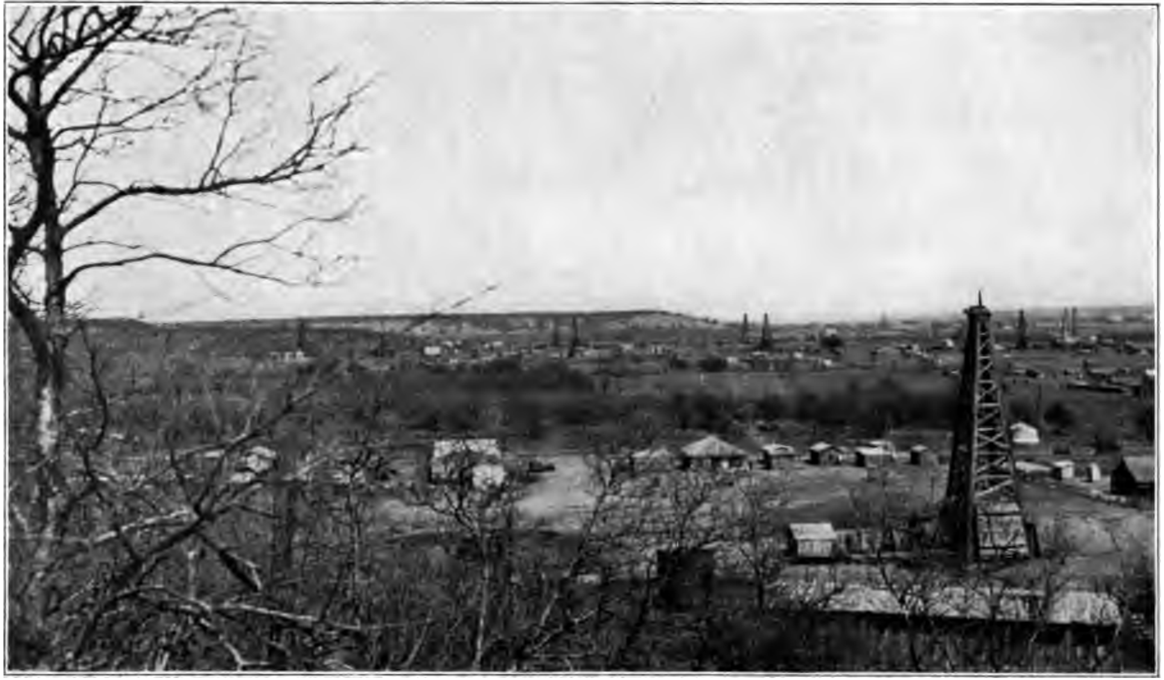
The production commenced in 1917 but has not yet become important.

Desdemona (Duke-Knowles) Oilfield (Comanche County)

This pool in the north corner of Comanche County, is 25 miles south of the town of Ranger. At present it is comprised of three or four square miles of highly productive territory in which every well is a large producer, and a bordering area, several miles wide, in which there are scattered wells with moderate yield.

The oil is in the "black lime" of the Bend Series at a depth of 2,650–2,900 feet. The principal oil sand is the Duke Sand, at about 2,700 feet. Some deeper productive horizons are now being found.

The field was discovered during 1918, and at the end of the year there were seven producers, which together were yielding over 4,000 barrels a day. During 1919 there has been great activity, and many big wells have been brought in. Some of them have had initial production 7,000 –10,000 barrels a day.



View No. 2. A part of the Ranger Oilfield

(Photograph lent by Dr. Ralph Arnold.)

There are also many valuable gas wells in this field, giving 5–30 million cubic feet of gas per day.

The production (December, 1919) is figured at 40,000 barrels a day, but at present many of the wells are "shut in," awaiting pipe lines, and it is estimated that the potential daily production of the field already exceeds 60,000 barrels a day,—which is nearly as great as that of the Ranger field.

Ranger Oilfield (Eastland County)

The Ranger pool in the northwest part of Eastland County lies due north of the Llano-Burnett uplift mass, at a distance of 80 miles from the outcrop of the Mississippian rocks which contain the oil.

The surface is occupied by the Pennsylvanian deposits, which have a general westerly dip. Only a very faint anticlinal structure is discernible at the surface in the Ranger field, though it is stated by geologists who have specially studied the drilling data, that at depth the fold is much more pronounced.

The production is found at a depth of 3,300–3,500 feet, within the Bend Limestone ("black lime"), the principal oil horizon occurring at about 200 feet down in the limestone.

The rock which actually bears the oil, according to the drilling records, is a sand now known as the Ranger Sand, with reported thickness varying from 10 to 47 feet.

The oil was found in 1917, when on October 25th, the McClesky Well came in at 2,000 barrels a day. Great enthusiasm was aroused by the discovery and hundreds of deep wells were soon commenced in the vicinity and throughout the surrounding country.

The rapid development of this deep field during 1918, was the most prominent event in the oil business of that year.

The largest wells had initial production of 6,000–7,000 barrels a day, and the total output for 1918 was over 6 million barrels.

A year after the date of its completion, the McClesky well was still making 500 barrels a day.

During 1919 there has been further great development, and there are now some hundreds of producing wells. By the middle of the year the output had grown to about 73,000 barrels a day. Subsequently it has slightly decreased.

The extent of the present producing area is 25–30 square miles. By the end of the year the total amount of oil taken out of this ground will be near 28 million barrels.

There is also a large production of gas, obtained both from the Pennyslvanian and from the Mississippian. Wells with daily capacity as high as 50–60 million cubic feet have been reported.

The oil is of high quality having specific gravity .84 (36.7 degrees Be) and yielding 28 per cent of gasoline (distillate up to 150 degrees C). The base consists of 1½ per cent paraffin and 1½ per cent asphalt.

Breckenridge and New Caddo Oilfields (Stevens County)

These two new oilfields are in the middle of Stevens County, are now merging into one continuous field. In May, 1919 a well, placed midway across the 8 miles of intervening territory, came in at 5,000 barrels a day, and many wells are now being drilled.

The surface in these fields is occupied by Pennsylvanian beds.

A valuable supply of gas is being obtained from the Strawn formation at 2,000–2,100 feet; but the oil is found in the "black lime" of the Bend Series at 3,150–3,450 feet.

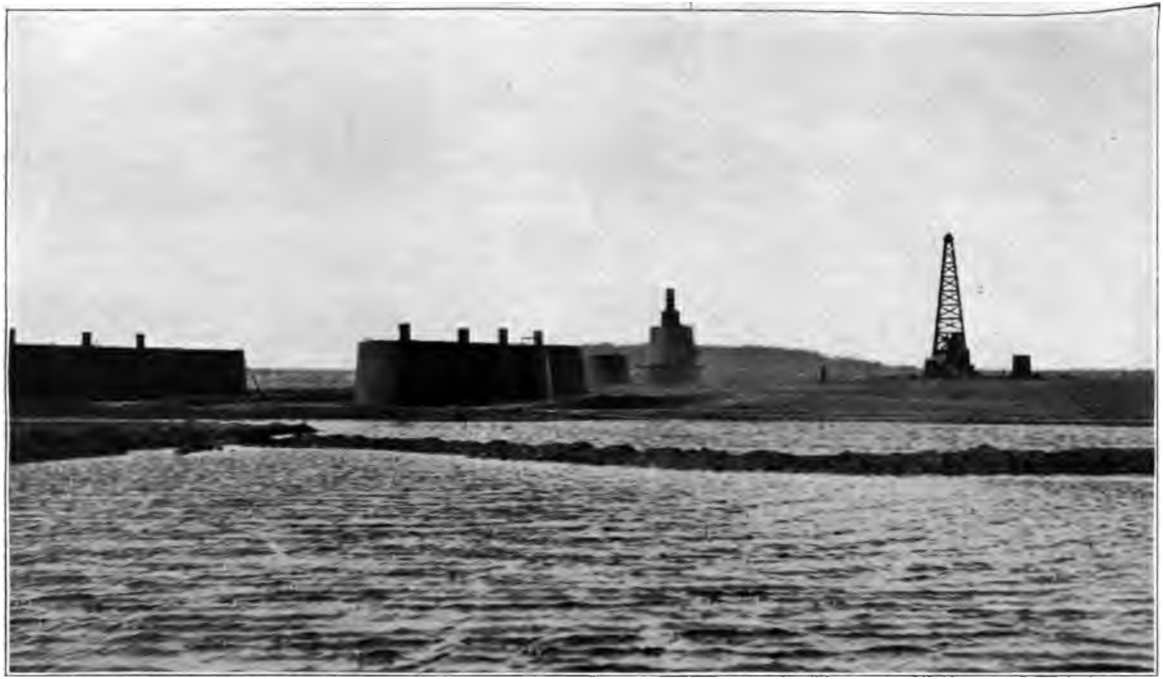
The discovery wells were drilled in 1917 and at the end of 1918, there were 29 wells producing oil with total daily output of about 10,000 barrels. The production for the year was 1,095,600 barrels.

There has been a further rapid increase in 1919, and the yield during the latter part of the year, has exceeded 40,000 barrels a day.

One of the best wells in north Texas was drilled near Caddo. It came in at over 12,000 barrels a day and has since been giving 10,000 barrels daily.

The oil is of notably high quality, having specific gravity .823 (40 degrees Be)

A large gas well was reported recently, 3 miles south of Breckenridge, having initial flow at the rate of 50 million cubic feet a day, from a depth of 3,100 feet.



View No. 3.   In the Ranger Oilfield—Reservoirs of oil coming from a big well, 5 miles northwest of Ranger.

(*Photograph lent by Dr. Ralph Arnold.*)

CHAPTER V

THE PENNSYLVANIAN AND LOWER PERMIAN SYSTEMS

SECTION A

GENERAL CHARACTER OF THE PENNSYLVANIAN AND LOWER PERMIAN

Most of the principal oil accumulations of the Mid Continent Oil Region are in the Pennsylvanian deposits.

The Pennsylvanian and the marine part of the Permian, comprise clay-shales, sandstones, calcareous shales, calcareous sandstones, limestones and coal seams.

The **clay-shales** constitute the bulk of the deposits. The greater part of them are of marine deposition, though many beds are rich in finely divided carbonaceous matter, and some contain well-preserved plant remains. The shales are of various colors. Encountered at depth, they are chiefly dark blue and black, gray and dark gray-green. There are also, occasionally, thin bands of white shale and red shale. Dark carbonaceous shales, of marine deposition, are found under most of the oilfields.

The **sandstones** sometimes have a thickness of 100 feet or more. Generally they are irregular and discontinuous, but some are traceable for distances of 50 miles. In texture they vary greatly, but in color, at depth, they usually are gray.

Bituminous **coal** occurs throughout the Pennsylvanian System, the quantity decreasing as we ascend from the lower to the higher series.

In the oilfield districts of Kansas and northern Oklahoma, the workable seams are chiefly in the Cherokee formation which is the lowest member; but there are mines also in the Bandera, the Chanute and the Severey formations.

In north Texas there are coal seams in the Strawn, the Canyon and the Cisco formations.

In the folded area of southeast Oklahoma, where gas occurs without oil, important coal deposits of higher quality occur.

The **limestone** beds are very numerous, and are the most conspicuous members of the System. Some 30 or more of them bear well-known names, many of these beds being continuous for 100–200 miles. Their thickness generally is from 5 feet to 30 feet, and occasionally reaches 50 feet. The main development of the limestones is in Kansas; and as we pass southward across Oklahoma, they are found to gradually thin out and fade away. Probably the sum of their thicknesses nowhere exceeds 600 feet, or 15% of the whole accumulation. Commonly these rocks are compact, white or pale gray limestones, often containing much chert. Usually they are only moderately rich in organic remains; but there are some bands largely composed of fossils, and some are oölitic. The abundant fossils are brachipods, a few lamellibranchs, crinoids, bryozoa, corals and sometimes many foraminifera of the genus Fusulina. In some cases, seams containing plant-remains are almost in contact with the limestone.

SECTION B

THE PENNSYLVANIAN AND LOWER PERMIAN IN KANSAS

In Kansas and northern Oklahoma, the stratigraphy of the Pennsylvanian has been much studied, and by means of the limestone bands, this System is divided up into a number of sub-formations or series. Unfortunately there is no standard scheme of subdivision, also there is some difference of opinion as to the horizon at which to draw the line between the Pennsylvanian and the Permian.

Probably the best classification for Kansas is that given by Moore and Haynes which is founded on the work of Haworth and others.

The accompanying columns (Figs. 10 and 12) give a pictorial view of the deposits. They show the Pennsylvanian 2,800 feet thick in Kansas and 3,400 feet thick in northern Oklahoma; and the Lower Permian is shown with a thickness of 1,200 feet in Kansas, and not delimited in Oklahoma.

We must observe, however, that the detailed information has been gathered chiefly at the outcrops, and the lowest and highest beds have their outcrops 100 miles or more apart. Consequently, in no one place is the vertical column actually as depicted, for there is much change in the character and thickness of the beds in a distance of 100 miles. Such lateral changes are illustrated in the accompanying plan of southeast Kansas (Fig. 11), which is adapted from work by Shrader and Haworth,* published in 1906.

Of the various subdivisions of the Pennsylvanian System, by far the richest is the Cherokee formation which probably has yielded 70% of the oil in the Mid Continent Fields.

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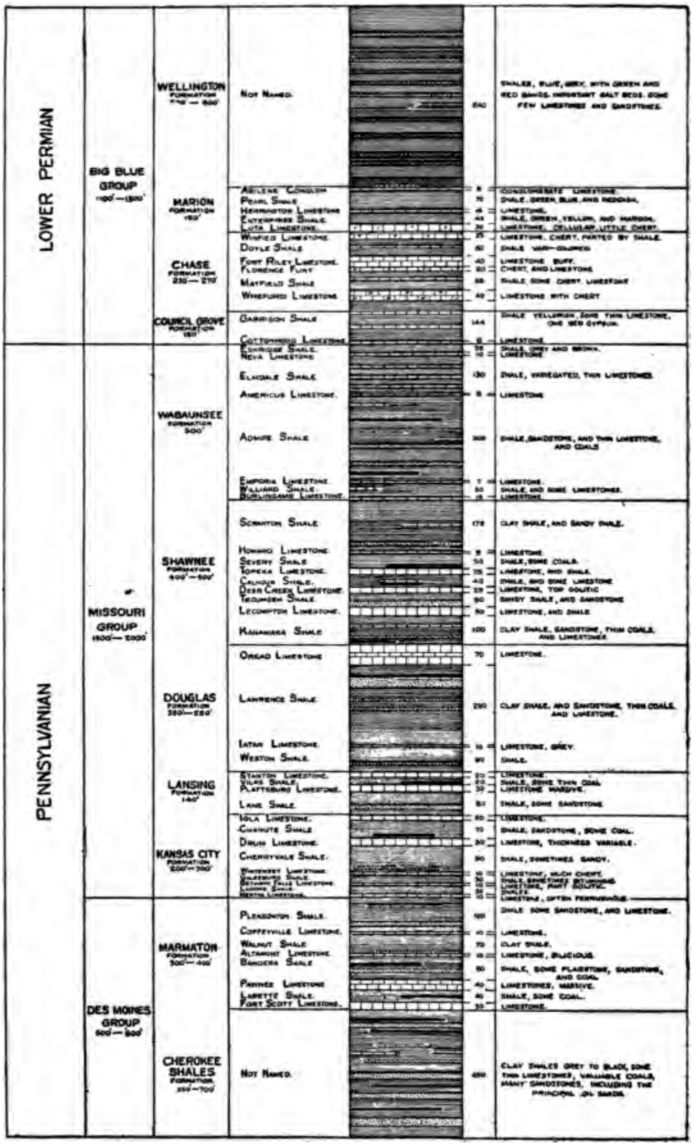
* U. S. Geological Survey, Bulletin 296.

FIG. 10.

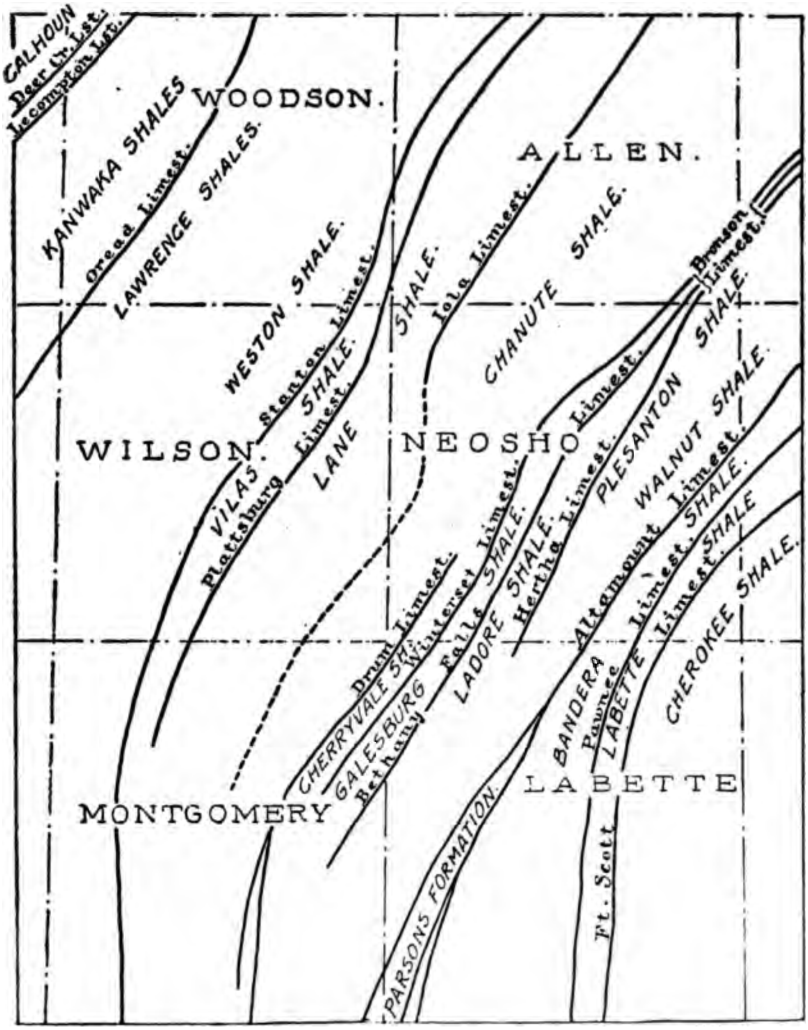
LOWER PERMIAN AND PENNSYLVANIAN
IN
KANSAS


LOWER PERMIAN
PENNSYLVANIAN
BIG BLUE GROUP 1100'—1300'
MISSOURI GROUP 1800'—2000'
DES MOINES GROUP 600'—800'
WELLINGTON FORMATION
MARION FORMATION 150'
CHASE FORMATION 230'—270'
COUNCIL GROVE FORMATION
WABAUNSEE FORMATION 500'
SHAWNEE FORMATION 400'—500'
DOUGLAS FORMATION 350'—550'
LANSING FORMATION 140'
KANSAS CITY FORMATION 200'—300'
MARMATON FORMATION 300'—400'
CHEROKEE SHALES FORMATION
NOT NAMED. 840 SHALES, BLUE, GREY, WITH GREEN AND RED BANDS. IMPORTANT SALT BEDS. SOME FEW LIMESTONES AND SANDSTONES.
ABILENE CONGLOM. 5 CONGLOMERATE LIMESTONE.
PEARL SHALE 70 SHALE, GREEN, BLUE, AND REDDISH.
HERINGTON LIMESTONE 15 LIMESTONE.
ENTERPRISE SHALE 45 SHALE, GREEN, YELLOW, AND MAROON.
LUTA LIMESTONE. 30 LIMESTONE, CELLULAR, LITTLE CHERT.
WINFIELD LIMESTONE 25 LIMESTONE, CHERT, PARTED BY SHALE.
DOYLE SHALE 60 SHALE VARI-COLORED.
FORT RILEY LIMESTONE. 40 LIMESTONE BUFF.
FLORENCE FLINT 20 CHERT, AND LIMESTONE.
MATFIELD SHALE 65 SHALE, SOME CHERT, LIMESTONE
WREFORD LIMESTONE 40 LIMESTONE WITH CHERT
GARRISON SHALE 144 SHALE YELLOWISH, SOME THIN LIMESTONE, ONE BED GYPSUM.
COTTONWOOD LIMESTONE 6 LIMESTONE.
ESKRIDGE SHALE. 35 SHALE, GREY AND BROWN.
NEVA LIMESTONE 10 LIMESTONE
ELMDALE SHALE 130 SHALE, VARIEGATED, THIN LIMESTONES.
AMERICUS LIMESTONE. 5 LIMESTONE
ADMIRE SHALE 300 SHALE, SANDSTONE, AND THIN LIMESTONE, AND COALS
EMPORIA LIMESTONE. 7 LIMESTONE.
WILLARD SHALE. 50 SHALE, AND SOME LIMESTONES.
BURLINGAME LIMESTONE. 15 LIMESTONE.
SCRANTON SHALE 175 CLAY SHALE, AND SANDY SHALE.
HOWARD LIMESTONE. 5 LIMESTONE
SEVERY SHALE 50 SHALE, SOME COALS.
TOPEKA LIMESTONE. 25 LIMESTONE, AND SHALE.
CALHOUN SHALE. 40 SHALE, AND SOME LIMESTONE
DEER CREEK LIMESTONE. 25 LIMESTONE, TOP OOLITIC
TECUMSEH SHALE. 60 SANDY SHALE, AND SANDSTONE
LECOMPTON LIMESTONE. 50 LIMESTONE, AND SHALE
KANWAKA SHALE 100 CLAY SHALE, SANDSTONE, THIN COALS, AND LIMESTONES.
OREAD LIMESTONE 70 LIMESTONE.
LAWRENCE SHALE 290 CLAY SHALE, AND SANDSTONE, THIN COALS, AND LIMESTONE.
IATAN LIMESTONE. 10 LIMESTONE, GREY.
WESTON SHALE. 90 SHALE.
STANTON LIMESTONE. 20 LIMESTONE.
VILAS SHALE. 20 SHALE, SOME THIN COAL
PLATTSBURG LIMESTONE. 30 LIMESTONE MASSIVE.
LANE SHALE. 80 SHALE, SOME SANDSTONE
IOLA LIMESTONE. 10 LIMESTONE.
CHANUTE SHALE 70 SHALE, SANDSTONE, SOME COAL.
DRUM LIMESTONE. 30 LIMESTONE, THICKNESS VARIABLE.
CHERRYVALE SHALE. 90 SHALE, SOMETIMES SANDY.
WINTERSET LIMESTONE. 10 LIMESTONE, MUCH CHERT.
GALESBURG SHALE. 30 SHALE, SOMETIMES BITUMINOUS
BETHANY FALLS LIMESTONE. 10 LIMESTONE, PART OOLITIC.
LADORE SHALE 30 SHALES.
HERTHA LIMESTONE. 10 LIMESTONE, OFTEN FOSSILIFEROUS.
PLEASANTON SHALE. 120 SHALE SOME SANDSTONE, AND LIMESTONE.
COFFEYVILLE LIMESTONE. 10 LIMESTONE.
WALNUT SHALE 70 CLAY SHALE.
ALTAMONT LIMESTONE 10 LIMESTONE, SILICIOUS.
BANDERA SHALE 80 SHALE, SOME FLAGSTONE, SANDSTONE, AND COAL.
PAWNEE LIMESTONE 40 LIMESTONES, MASSIVE.
LABETTE SHALE. 40 SHALE, SOME COAL.
FORT SCOTT LIMESTONE. 30 LIMESTONE.
NOT NAMED. 450 CLAY SHALES GREY TO BLACK, SOME THIN LIMESTONES, VALUABLE COALS, MANY SANDSTONES, INCLUDING THE PRINCIPAL OIL SANDS.

LOWER PERMIAN AND PENNSYLVANIAN IN KANSAS

System	*Group*	*Formation*	*Member*	*Thickness*	*Description*
MIAN	—1,300	Wellington Formation 500–800	Undifferentiated	500–800	Blue-gray clay-shales, with greenish and reddish bands. Very little limestone. Important salt beds.
		Marion Formation 150	Abilene Conglomerate	5	Conglomeratic limestone.
			Pearl Shale	70	Shales of green, blue and reddish color.
			Herington Limestone	12–15	Massive, very fossiliferous limestone.
			Enterprise Shale	35–44	Shales of yellow, green and maroon color.
			Topeka Limestone	20–25	Blue and buff limestones and shale.
			Calhoun Shale	50	Shale with some thin

FIG. 11.



Outcrops of the principal limestones of the Pennsylvanian, in southeast Kansas.

(After Shrader and Haworth, U. S. Geol. Surv.)

The characters of these strata are therefore worth special notice. In Kansas, their description is summarized by Moore and Haynes * as:

"A succession of shale and sandstone with beds of coal and discontinuous limestone layers at certain horizons. Shale constitutes by far the greatest part of the formation, although the proportion of sandstone is very important. Limestone is almost negligible in quantity. There is considerable lithologic variation, both vertically and laterally, in the Cherokee shale. The color ranges from light ash-gray to yellowish brown and jet-black, and there are changes in the material from finest grained clay-shale to very sandy shale and sandstone. Sandstone beds are very abundant throughout the Cherokee, but are not of sufficient persistency to be of value in stratigraphic study. They are the source of most of the production of southeastern Kansas and the adjacent portion of Oklahoma, and possibly also in the Butler County field."

The oil sands of the Pennsylvanian as a rule afford little or no indication at their outcrops to signify that they are oil bearing. Apparently any sandstone of ordinary appearance may prove to be an oil sand when drilled into at a place where there is anticlinal structure. At some localities, however, slight showings of oil occur. Seepages of oil in Miami County were described by Dr. C. W. Brown as early as 1855 and near them in 1860, he drilled a successful well. [But it was not until 1903–1904 that extensive exploitation of the Kansas fields took place. An outline of the events is contained in Part III.]

The early fields were situated along the east border of the State, on or near the outcrop of the Cherokee formation. They produced abundantly at depths of a few hundred feet, from the Bartlesville and other sands.

In this district the Bartlesville Sand, which has yielded

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* State Geological Survey, Bulletin 3.

90% of the oil in southeast Kansas and northeast Oklahoma, lies about 100 feet above the Mississippian Limestone.

As the older fields became exhausted the development was continued westward and higher productive horizons were found, distributed throughout almost the whole of the Pennsylvanian pile of deposits. During the past three years the greater part of the oil output of Kansas has come from the Augusta-Eldorado fields of Butler County, where the oil sands appear to be higher than the Cherokee. The highest bed from which commercial production is obtained is the shallow Sand at Eldorado which is within a few hundred feet of the top of the Pennsylvanian.

The following table gives an approximate idea of the distribution of the oil in the column of the Pennsylvanian beds in Kansas. In many cases, especially the western fields, the horizon of the oil sand is not known exactly, and the position ascribed is only roughly approximate.

DISTRIBUTION OF PRODUCTIVE HORIZONS IN THE PENNSYLVANIAN OF KANSAS

Series	*Sand*	*Production*	*Oilfield*	*County*	*Depths*
Admire	Shallow	Oil	Eldorado	Butler	600–700
Willard	Gas	Gas	Dexter	Cowley	Shallow
	Shallow	Gas	Arkansas City	"	"
Lawrence	Sand	Oil	Winfield	Cowley	1,450
	Sand	Gas	Augusta	Butler	1,450
Weston (?)	Sand	Oil	Winfield	Cowley	1,700
	Sand	Oil	Eldorado & Augusta	Butler	1,750
Cherryvale	Varner	Oil	Eldorado & Augusta	Butler	2,500
	"	Oil	Elbing	"	2,500
	"	Oil	Peabody	Marion	2,500
Pleasanton	Sand	Oil	Rantoul	Franklin	Shallow
	Sand	Oil	Paola	Miami	Shallow
	Sand	Oil	Longton	Elk	650
	Red, or Stray	Oil	Sedan	Chautauqua	1,060
Bandera	Peru	Oil	Sedan-Peru	Chautauqua	1,200
	Hancock	Oil	" "	"	1,300
Cherokee	Wayside	Oil	Wayside	Montgomery	600
	Wieser	Oil	"	"	700
	Bartlesville	Oil	"	"	1,100
	"	Oil	Sedan-Peru	Chautauqua	1,100–1,300
	"	Oil	Chautauqua	"	1,500
	"	Oil	Caney	Montgomery	1,400
	"	Oil	Coffeyville	"	350–600
	Bartlesville or others	Oil	Independence	"	450–600
	" " "	Oil	Cherryvale	Labette	700–800
	" " "	Oil	Neodesha	Wilson	800–900
	" " "	Oil	Erie	Neosho	500–600
	" " "	Oil	Chanute	Neosho	
	" " "	Oil	Humboldt	Allen	700–900
	" " "	Gas	Iola	"	

OILFIELDS OF KANSAS PRODUCING FROM THE PENNSYLVANIAN

The following notes, in small type, relating to individual oilfields, are gathered from many sources. The more recent items are from the various oil journals.

Iola Gasfield (Allen County)

This field occupied the east central part of Allen County, around Iola and Gastown.

The surface is formed by the Iola Limestone and the overlying Lane Shales, which are dipping westward at 10–15 feet per mile. The productive sands lie at depth 600–900 feet. The main gas sand was found at 840 feet.

The exploitation for gas in this area began as early as 1873 but no important supply was obtained until 1895. The initial pressure was 325 lbs and some of the wells have yielded 10–15 million cubic feet per day. Oil also is obtained in a number of the wells, but few of these give more than 25 barrels a day. The gas has been much used at Iola in the zinc smelters and in the brick and cement works, etc.

Moran Oilfield (Allen County)

Both west and east of Moran, at the east side of Allen County, there is production of oil and gas.

The surface is occupied by the Cherryvale Shales, Chanute Shales and Iola Limestone; and the oil is found at depths less than 1,000 feet.

The first important development of this field was in the year 1902–1903, when 19 producers were brought in. There are now about 100 oil wells in the vicinity.

Humboldt Field (Allen County)

In the southwest part of Allen County around Chanute, there is an important oil and gas field extending over more than 50 square miles. The field continues southward into Neosho County around Chanute, where it covers a still larger area. The whole is referred to as the Chanute-Humboldt field.

The Iola Limestone and the Lane Shales occupy the surface, and the oil and gas are found chiefly at 800–900 feet.

A number of wells were drilled in 1894–1895 and the town was supplied with natural gas, but the main development was in 1903–1904. There was also renewed activity in 1916.

Greeley Field (Anderson County)

Some small production of oil and gas has been obtained from wells near Greeley, Garnett, Kincaid and other localities in Anderson County, but no important field has been developed.

The surface is occupied by the Lansing and Douglas formations.

Augusta-Eldorado-Towanda Oilfields (Butler County)

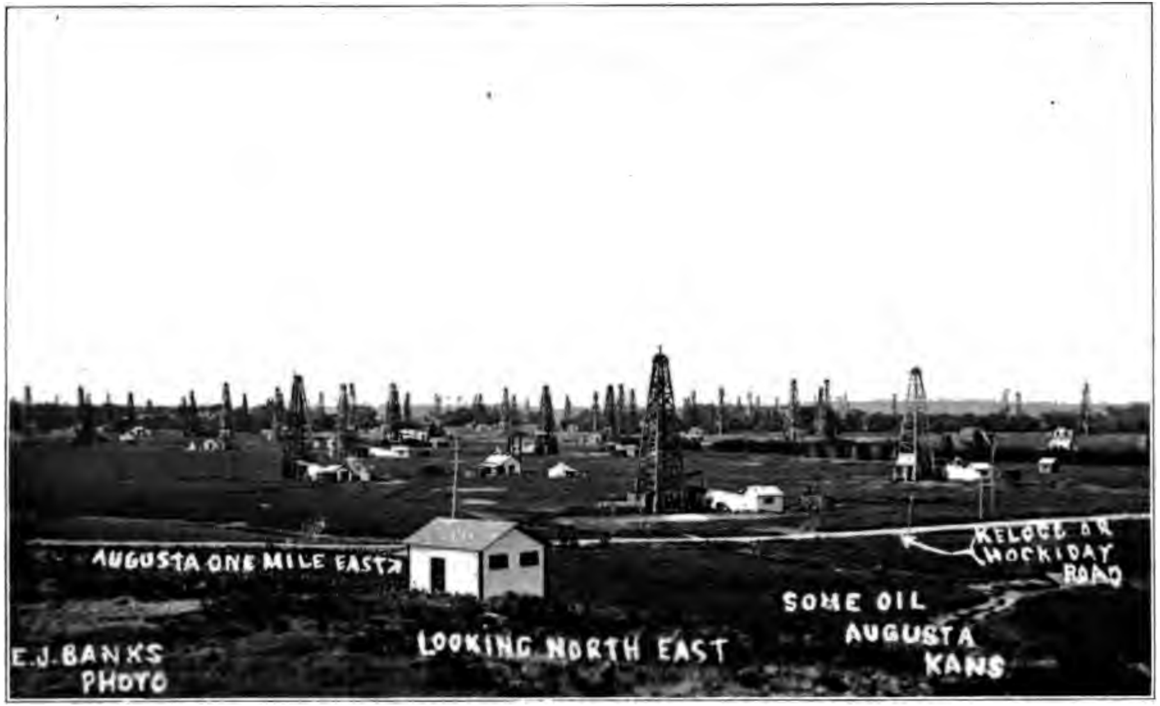
It is convenient to deal with these fields together, as they form a group, 60 miles west of the older oilfields.

The surface in this district is occupied by the lower members of the Permian; and the productive ground is situated along well-defined anticlinal and dome structure, extending in a N. N. E. direction for 27 miles.

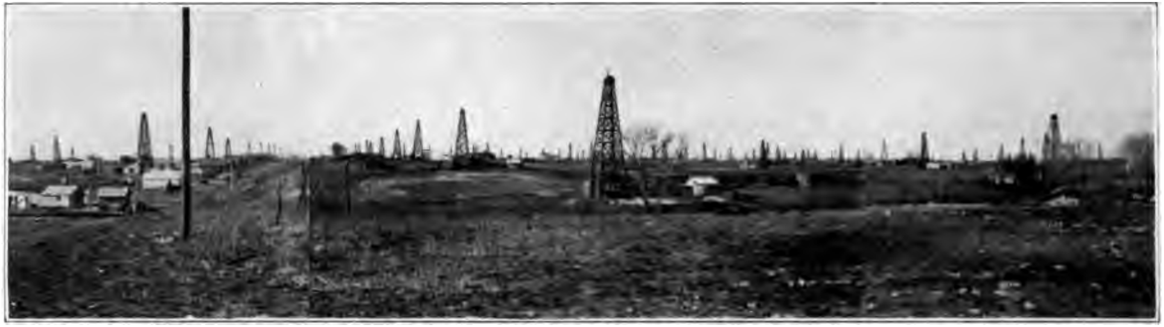
The field consists of three main parts:—(1) A large pool on a dome west of Eldorado; (2) a smaller pool, 6 miles southwest of it, on an anticline west and north of Augusta; (3) a fairly large pool on an elongated dome extending from Augusta southward as far as Gordon, and sometimes called the Augusta-Gordon field.

The oil and gas are obtained from several sands in the Pennsylvanian, whose exact horizons are not established.

Eldorado Shallow Sand " " " "	at 650 ft. at 750 ft. at 850 ft.	Moderate production at Eldorado.
Augusta Gas Sand	at 1,450 ft.	The gas sand of the original gasfield.
Upper Oil Sand	at 1,750 ft.	Moderate production.
Varner Sand	at 2,450 ft.	Great production.



View No. 4. The Augusta Oilfield.



View No. 5. The Eldorado Oilfield.

(Photograph lent by Mr. A. E. Fath.)

The first exploitation was at Augusta, where in 1913–1914 a valuable gasfield was developed at depth 1,500 feet. Late in 1914 the Varner oil sand was discovered, and soon arich field was proved.

At first the Augusta pool was the most prolific (see view No. 4), but in 1917 the Eldorado portion of the field (see view No. 5) had become the more important and in 1918 the westward extension of it, near Towanda, afforded the most conspicuous results.

The Augusta-Eldorado oilfield is one of world's notable fields. In five years (to the end of 1919), it has yielded nearly 100 million barrels of oil from an area of 35 square miles. It has provided the largest wells of the Mid Continent region. A number of them have given 12,000–15,000 barrels a day and in some instances there were flows of 20,000 barrels a day. One well has produced 2¼ million barrels of oil. (See view No. 1.)

The output reached a maximum in April, 1918, the figure being 115,850 barrels a day. Since that date there has been a rather rapid decline and at the end of 1919, the daily yield was about 57,000 barrels.

It is stated that Helium to the extent of 2 per cent, is present in some of the natural gas in this field, met with at 600–1,200 feet. This is a higher percentage than has been found in any other natural gas.

(For further particulars see also Part VII.)

Douglas Oilfield (Butler County)

Two miles north of Douglas, there is a small group of productive wells which are best considered as belonging to the Augusta-Eldorado Oilfield. They are two miles south of the Augusta-Gordon pool. The production is at 1,800 feet.

Potwin Oilfield (Butler County)

A number of wells have been drilled near Potwin, 8 miles northwest of the Eldorado field, but there are not many producers.

Peabody-Elbing Oilfield (Butler and Marion Counties)

In the northwest corner of Butler County an important new pool has been opened, a few miles east of Elbing.

The wells are 8 miles north of Potwin and 12 miles N. N. W. of the Eldorado field. A number of them are yielding two or three hundred barrels a day. The best wells have "come in" at 2,000–3,000 barrels.

The surface is occupied by beds belonging to the lower part of the Permian; and the main sand is found at 2,400–2,500 feet, as in the Augusta-Eldorado field.

In May, 1919, a good well was drilled 3 miles northeast of the Elbing pool, between it and the new Peabody field in the south of Marion County, demonstrating that the two oilfields are connected. Towards the end of 1919 the output of the Peabody-Elbing district had reached 16,000 barrels a day.

Hale Field (Chautauqua County)

A valuable gasfield near Hale, in the northeast part of the county, was developed in 1907–1908. The wells give about 5 million cubic feet a day.

Peru-Sedan Field (Chautauqua County)

Around Sedan, Peru, and Chautauqua, in the center and south of the county, there are large groups of oil wells spread over an area of some hundred square miles or more.

The surface in this field is occupied by various members of the Pennsylvanian, mostly from the Weston Shales up to the Deer Creek Limestone.

The production is from the following three sands:—

Red or Stray	Productive chiefly around Sedan	150 feet above Peru Sand
Peru	Main productive sand of district	300 feet above Bartlesville Sand
Bartlesville	Productive in south part of the country	200 feet above Mississippi Lime

The depths of the wells are generally from 600 to 1,600 feet.

The principal exploitation was during 1904, when 566 producers were brought in. Development is still active in these fields and from 1912 onwards there have been 200–500 wells drilled each year.

Arkansas City Gasfield (Cowley County)

A valuable gasfield has been developed immediately north of Arkansas City.

The formation at the surface belongs to the lower part of the Permian, somewhat above the Wreford Limestone.

There are a number of gas sands, but the principal producer lies at a depth of 3,200 feet. Some of the wells are capable of yielding 15–70 million cubic feet of gas per day.

Winfield Oil and Gasfield (Cowley County)

A number of wells have been drilled south and east of Winfield, to sands at 1,450 and 1,700 feet.

There is a valuable production of gas; and oil is obtained from a few wells.

Dexter Oilfield (Cowley County)

Some oil has been obtained from several wells at Dexter, depth 2,700–3,000 feet.

A strong flow of gas was struck, at 400–500 feet, which contained 82.70 per cent of Nitrogen and 1.84 per cent of Helium. Until recently this was the largest percentage of Helium known. Being of no value at the time when it was discovered, in 1904, this "wind gas" was allowed to go to waste. The supply is now exhausted.

Longton Oilfield (Elk County)

In the southeast part of Elk County there is a small oilfield near Longton.

The chief oil sands lie at about 600 feet and 1,600 feet. The wells are only small producers.

At several other localities in this county there is some small production of oil.

Rantoul-Wellsville Oilfield (Franklin County)

In the northeast part of Franklin County, along the east border of it, there is productive territory near Rantoul; Peoria; and south of Wellsville. The field extends eastwards into Miami County.

The surface is occupied by the Stanton-Plattsburg Limestone and the Lane Shales.

There are several oil sands, at depths mainly between 350 and 800 feet, and the yield of the wells is 5–60 barrels a day. There is also some valuable production of gas, especially at Peoria.

The field was developed in 1905 and 1906, in which years 135 wells were drilled. Activity has been renewed from time to time, notably in 1914, when 225 wells were completed. At Wellsville a number of wells were drilled in 1915 and 1916, giving an average yield of 11 barrels a day. The development is still proceeding, and in May, 1919, there were 38 drilling rigs at work in the Franklin County part of the field, and 70 in Miami County. Some of the new wells are coming in at 20–60 barrels a day, obtained from the "Shoestring" Sand.

Eureka-Sallyards Oilfield (Greenwood County)

In the west part of Greenwood County some production has been developed during the past three years.

The rocks at the surface belong to the Wabannsee formation.

The oil is found chiefly at 1,600–2,000 feet.

Early in 1917 there was some small amount of oil at Eureka at a depth of 1,600 feet. In May, 1919, a 250-barrel well in this sand has been reported.

Later in 1917 some production at 2,400–2,500 ft. was obtained west of Eureka near the county boundary. Some wells have come in at 100–250 barrels a day, but most of them produced 10–50 barrels.

Olathe Field (Johnson County)

Some useful gas wells have been obtained in Johnson County; also a few small oil wells giving 10–20 barrels a day.

The beds at the surface are the Lansing and Douglas formations; and the production is from the Cherokee.

Mound Valley Oilfield (Labette County)

At the west edge of Labette County, west of Mound Valley, there is an important gas and oil field, which continues westward to the fields of Cherryvale and Independence in Montgomery County. Drilling has been proceeding in the district from 1903 up to the present time.

West and north-west of Mound Valley the field produces chiefly gas, which is found in sands at 600–700 feet. The oilwells lie mainly southwest and also southeast of Mound Valley. Thirty-one oilwells were drilled in 1904, and there has also been considerable drilling in the past few years.

Mound City Field (Linn County)

There is a small production in Linn County from wells near Mound City and at several other localities.

The rocks at the surface belong to the Marmaton and Kansas City formations, and the oil sands are reached at 400–700 feet.

The wells are only small producers.

Peabody-Elbing Oilfield (Marion and Butler Counties)

Activity in Kansas is now largely centered in the new field at the south edge of Marion County, about 18 miles north of the Eldorado oilfield. The successful wells extend over the border into Butler County to the new pool at Elbing. The limits of the field are not yet determined.

Production is obtained from sands at 2,100–2,500 feet, which presumably are the same as in the Augusta-Eldorado oilfields. Many of the wells have come in at 500–3,000 barrels a day.

The output of the Peabody-Elbing field towards the end of 1919 had reached 16,000 barrels a day.

Paola Oilfield (Miami County)

This field extends from around Paola, in the center of Miami County, to the western margin, where it is practically continuous with the Rantoul oilfield of Franklin County.

The surface is occupied by the Iola Limestone, the Lane Shale and the Stanton-Plattsburg Limestone.

The oil and gas are found chiefly in the Cherokee shales but also to some extent in the Marmaton formation.

The depth of the wells is generally 300–600 feet, and the initial production ranges up to 200 barrels a day.

The first wells in Kansas were in this district, and the town of Paola was supplied with natural gas as early as 1884. Oil in commercial quantity was obtained in 1889, but the principal development was in 1904 and 1905, when some 300 wells were drilled.

In 1915 a new area of shallow oil was found 7 miles northwest of the older wells, and a number of wells were drilled. In 1916 there was much drilling in Paola on the town lots.

Cherryvale Oilfield (Montgomery County)

Oil and gas wells are spread over almost the whole of Montgomery County, and the various fields are continuous with one another. The Cherryvale oil and gasfield is in the northeast of the county.

The surface is occupied mainly by the Winterset Limestone and the Cherryvale Shales. The chief oil sand is reached at 700–800 feet, and some of the wells produce 100 barrels a day.

This field is one of the early developed areas of Kansas, and the town of Cherryvale has been supplied with natural gas since 1893. The gas is much used in the zinc smelters and in the extensive brick works.

Independence Field (Montgomery County)

This oil and gasfield, in the middle of Montgomery County, is practically continuous with several surrounding fields, which all together occupy almost the whole county.

Independence is renowned rather for its gas than for its oil. The town was supplied in 1892.

The rocks at the surface are the Drum Limestone, Lane Shales, Chanute Shales, etc., and the production is chiefly at 700–1,200 feet depth.

Many of the oil wells have flowed 1000 barrels a day and the gas wells have capacity up to 37 million cubic feet a day.

The principal development was in 1903–1905, and also from 1912 to the present time.

Bolton Oilfield (Montgomery County)

This field lies between the Independence and Wayside fields, and is continuous with them.

The Lane Shales and Chanute Shales occupy the surface, and the oil lies at 700–1,200 feet.

Many of the wells at first gave two or three hundred barrels of oil per day.

The principal development was during 1903–1905. In 1905 there were about 200 producing wells.

Wayside Oilfield (Montgomery County)

This field, in the southwest of the county, is continuous with the Bolton, Tyro and Caney fields.

The rocks at the surface are the Stanton Limestone and the Weston Shales.

The productive sands are:

Wayside Sand	at 600 feet.
Wieser Sand	at 700 feet.
Bartlesville Sand	at 1,100 feet.

The wells are not large producers, but they continue steadily for a long time; and the field is still an area of active operations.

Coffeyville Oilfield (Montgomery County)

This oil and gasfield, in the southeast corner of the county, is practically continuous with the Cherryvale, Independence, Bolton and Tyro fields, which lie to north and west of it.

The Coffeyville Limestone is at the surface, and the oil was found at 350–500 feet.

The principal development was in 1902–1904; but as long ago as 1892 the town was supplied with natural gas.

Tyro Oilfield (Montgomery County)

The Tyro field, at the south edge of the county, lies between Caney and Coffeyville.

The surface is formed by the Lane Shales and Weston Shales; and the oil is found at 1,000–1,300 feet.

This field was opened in 1903, and some of the early wells flowed as much as 250 barrels a day. There has also been considerable recent development in this district.

Caney Oilfield (Montgomery County)

This field, in the southwest corner of the county, is continuous with the Wayside field to northward and the Tyro field to the eastward.

The Weston Shales are at the surface, and the oil and gas are found at about 600–1,400 feet. The oil-wells are small producers, but there were gas wells yielding 10–20 million cubic feet per day.

Elk City Gasfield (Montgomery County)

A valuable gasfield has been developed, during the past two years, near Elk City in the northeast of Montgomery County. It is now one of the most prolific gasfields in the country.

The surface in this district is occupied by the Weston Shales.

Many of the wells are capable of yielding 20–50 million cubic feet a day, and it was stated at the close of 1918, that the wells shut in, awaiting the construction of a pipe line, had a total capacity of 400 million cubic feet a day. Towards the end of 1919 it was stated that there were 51 productive wells occupying an area of 3 square miles, and having a total open flow capacity estimated at 1,440 million cubic feet.

Chanute Field (Neosho County)

This large oilfield is in the northwest part of Neosho County, and is continuous with the Humboldt field to northward of it in Allen County. Together the whole field is known as the Chanute-Humboldt oilfield.

The surface is occupied mainly by the Cherryvale Shales, but the wells are spread also over the outcrops of the Chanute Shales and the Lane Shales. There is well-defined anticlinal structure in the field. The oil lies principally at 700–900 feet.

Drilling in the district was commenced in 1894 and the town of Chanute was soon supplied with natural gas. The important oil production was developed in the years 1900–1904, since which time the drilling has been continuous up to the present day. In

1917 there were 651 producing oil wells in this county, most of which are in the Chanute field.

At present most of the oil wells are small producers, but some of them have given 500 barrels a day when the field was young. Some of the gas wells have had capacity as high as 30 million cubic feet per day.

Erie Oilfield (Neosho County)

This field, in the middle of Neosho County, is continuous with the Chanute oilfield to the northwest.

The surface is occupied by the Ladore Shales, and the oil is found at small depth. Some of the early wells at first gave 100–200 barrels a day, but most of the wells now are small producers, yielding 5–10 barrels a day.

Drilling at this locality was begun in 1900, and in the year 1903 there were 14 gas wells and 7 oil wells. Extensive development commenced in 1904.

Thayer Oilfield (Neosho County)

In the southwest part of the county there are groups of oil wells both east and west of Thayer.

The rocks at the surface here are the Chanute Shales.

Some oil wells were drilled in this field as early as 1893.

Buffalo Oilfield (Wilson County)

At Buffalo in the northeast part of Wilson County there is a field of oil and gas wells, giving small production from a depth of 900–1,000 feet.

The surface is occupied by the Stanton Limestone.

Altoona Field (Wilson County)

Around Altoona, and northeastward in the east part of the county, is a small oil and gasfield. The surface is formed by the Lane Shales.

Freedonia Field (Wilson County)

The Freedonia oil and gasfield lies in the west central part of Wilson county, where the Weston Shales are at the surface.

This field was opened during 1907, and there was renewed activity in 1916 and 1917, when a number of satisfactory wells were obtained giving 10–20 barrels of oil a day.

There also were many gas wells yielding a few million cubic feet per day.

Neodesha Oilfield (Wilson County)

This oil and gasfield is in the south part of Wilson County, and continues southward into Montgomery County.

The formations at the surface are mainly the Cherryvale Shales and the Lane Shales. Some well-defined folds occur. The production is from the Cherokee formation, at 800–1,000 feet depth.

Drilling commenced in 1893 and the town was supplied with gas in 1894. The initial pressure was 425 pounds, in a sand at 984 feet, and an important gasfield was soon developed. In 1894 also the first oil well was brought in, at about 10 barrels a day.

Neosho Falls Field (Woodson County)

In the northeast corner of Woodson County there are small oilfields at Neosho Falls and Vernon.

The surface is occupied by the Weston Shales. The wells are only small producers.

Yates Center Oilfield (Woodson County)

This small field is situated in the middle of Woodson County. The beds at the surface are the upper part of the Weston Shales, and the principal oil sand is found at about 1,100 feet.

Some of the wells are said to produce as much as 100 barrels of oil per day.

Toronto Oilfield (Woodson County)

In the southwest corner of Woodson County and at the east edge of Greenwood County there are some oil wells near Toronto.

The surface is formed by the Lawrence Shales and Oread Limestone; and the top of the Cherokee formation is reached at 1,100 feet.

The wells are only small producers.

Bonner Spring Field (Wyandotte County)

Some of the earliest attempts to find oil in Kansas were made in Wyandotte County. Wells were drilled at several localities and small amounts of gas and oil were obtained.

The surface is formed by the Lansing and Douglas formations; and the productive measures were reached at a few hundred feet.

SECTION C

THE PENNSYLVANIAN AND LOWER PERMIAN IN NORTHERN OKLAHOMA

In the north half of Oklahoma, the deposits are very similar to those of Kansas and the same system of subdivision perhaps might be applied, but in this State the study of the stratigraphy is not so far advanced, and some of the beds have not yet been classified. The column is represented graphically in Figure 12.

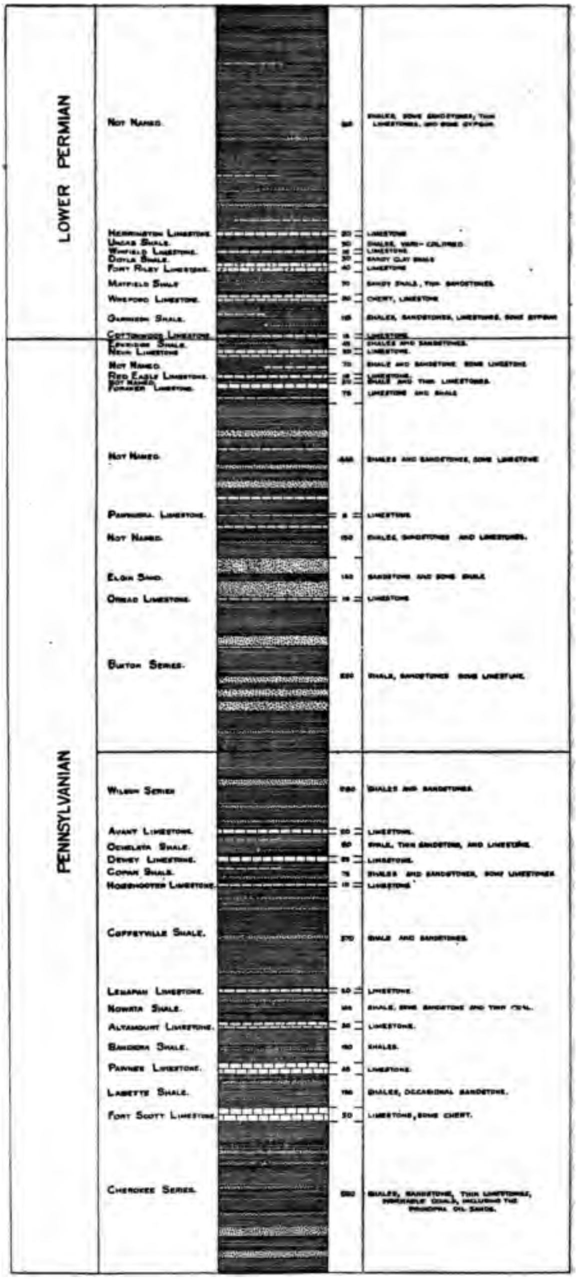
The following table, compiled from many sources, gives an idea of the character of the accumulation.

	Lower Permian in Northeast Oklahoma		
LOWER PERMIAN	Unclassified	1000	Shales, sandstones and thin limestones
	Herrington Limestone	20	Limestone, lower part massive.
	Uncas Shale	50	Vari-colored shales.
	Winfield Limestone	15	Gray massive limestone, brachipods abundant.
	Doyle Shale	30	Sandy clay-shales; some red seams.
	Fort Riley Limestone	40	Beds of hard limestone separated by shale.
	Matfield Shale	70	Sandy shale with thin red sandstones.
	Wreford Limestone	14–40	Limestone with much chert, many fossils.
	Garrison Shale	116	Shales and some sandstone.
	Cottonwood Limestone	15	Limestone with many fossils. Part is oölitic.

	Pennsylvanian in Northeast Oklahoma		
PENNSYLVANIAN	Eskridge Shales	45	Shales and sandstone.
	Neva Limestone	20	Massive beds of limestone, many fossils.
	Unnamed	70	Shale and sandstone, some limestone.
	Red Eagle Limestone	15	Thin bedded limestones.
	Unnamed	18	Shales and thin limestone.
	Foraker Limestone	74	22 ft. massive limestone, 52 ft. shales and limestone, fusulina abundant.
	Unclassified	400	Shales, sandstone and some thin limestone.
	Pawhuska Limestone	5	Gray limestone.
	Unnamed	130–150	Shales, sandstone and limestone.
	Elgin Sand	50–140	Massive sandstone passing laterally into sandstone and shale.
	Oread Limestone	0–17	Limestone.
	Buxton Series	450–600	Clay-shale; sandstones; some limestones.
	Wilson Series	180–300	Sandstones and clay-shale.
	Avant Limestone	0–35	Limestone.
	Ochelata Shales	45–90	Shales, thin sandstone, thin limestones.
	Dewey Limestone	23	Bluish semicrystalline limestone; abundant fossils; especially corals.
	Copan Shales	75	Shales and sandstones; some thin limestones; some oil sand.
	Hogshooter Limestone	10	Thin bedded limestone.
	Coffeyville Shale	370	Clay-shale and oil sands.
	Lenapah Limestone	20	Dense blue semicrystalline limestone with fossils.
	Nowata Shales	50–130	Bluish and greenish clay-shale, some sandy shale, also some coal-seams.
	Altamount Limestone	30	Massive, hard, highly silicious limestone.
	Bandera Shale	0–120	Bluish to black shales.
	Pawnee Limestone	43	Massive and fine-grained limestone.
	Labette Shale	120	Thick shales; occasional sandstones.
	Fort Scott Limestone	38–65	Massive fossiliferous limestone bed; some shale; some chert
	Cherokee Series	450–600	Shales, sandstones, thin limestones, workable coals; includes the principal oil sands.

Fig. 12.

LOWER PERMIAN AND PENNSYLVANIAN
IN
NORTHERN OKLAHOMA



The deposits in Oklahoma are similar in character to those of Kansas, consisting mainly of clay-shales and sandstones together with many limestone bands and some useful coal seams. The same dark carbonaceous shales are present throughout the oilfields and appear as the probable source of origin of the oil.

The limestones become less prominent as we pass southward from the Kansas border, but the sandstone, on the other hand, is present in increasing quantity and there is some thickening of the whole system, especially in the basal portion of it.

Further southward in Oklahoma (but still in the north half of that State, and amidst the principal oilfields) the thickness of the Pennsylvanian increases considerably. Sandstones are more numerous and thicker, whilst the amount of limestone is much decreased. A number of the prominent limestone beds have died out completely, and others have become parted into two or more thin seams with a thick mass of shales and sandstones between.

The Cherokee Series, as in Kansas, contains most of the oil. The following is a section of the Cherokee beds in Oklahoma measured at the outcrop east of the oilfields of Claremore, Birds Creek, Collinsville, etc., which are in the center of the Oklahoma fields.

Section * (from 1 mile east of Pryor Creek to Claremore).

Shale with a few interbedded sandstones..........	135 feet.
Massive, medium-grained sandstones............	17 "
Shaly sandstone..............................	3 "
Argillaceous, heavily-bedded, fossiliferous limestone	2½
Shaly sandstone..............................	8 "
Massive, medium-grained sandstone.............	37 "
Bluish shale..................................	35 "
Carbonaceous shale, capped by 6″ of ferruginous, silicious limestone...........................	3 "

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* D. W. Ohern, Research Bulletin No. 4, University of Oklahoma.

Gray, fine-grained sandstone	7 feet.
Arenaceous shale	70 “
Alternating shales and sandstones	70 “
Argillaceous, fossiliferous limestone	8 “
Massive, medium-grained sandstone	14 “
Bluish shale, weathering to a light yellow, and a few interstratified sandstones	550 “

The thickness of the Cherokee Series, in Kansas, is 400 feet, but in Oklahoma it attains to as much as 1,080 feet where exposed to eastward of the Glenn field and Muskogee. In this district, a small unconformity is found within the Pennsylvanian system, near its base, and a series of limestone-shales and sandstones, about 120 feet thick, known as the Morrow Formation, intervenes between the Cherokee and the Mississippian. The unconformity probably dies out in a short distance northward and westward; and the Morrow beds, if they continue, are included in the Cherokee.

The oil sands, as a rule, do not at the outcrop give any special sign of their importance, though in some places small seepages occur. Owing to their lenticular character, it is not practicable to identify the sandstone met with at depth in oil wells, with those found at the outcrops, which are 20–100 miles distant. In general, no one has ever seen the oil sands; consequently a productive sand is named from the place where the oil is first found; and the best that can be done is to estimate its probable approximate horizon.

In some pools, only one sand is productive, but more often there are two, and sometimes three or four, and occasionally five or six. In these cases apparently there is no connection between the accumulations, which occur one above another, and may be from 50 to 2,000 feet or more apart. For example, in the Cushing field, oil is being obtained from six sands, and several others are yielding gas.

In the Cleveland field also there are six producing sands. When there is more than one productive sand, separate wells are drilled, and it is usual to see wells arranged in pairs, each pair consisting of a deep well and a shallow well side by side.

Of all the oil sands the most celebrated is the Bartlesville Sand which has been the chief producer in most of the fields of northeast Oklahoma and southeast Kansas. It received its name from the Bartlesville district, in which it gave a prolific yield. It was also the chief producing sand of the great fields of Glen and Cushing and the older fields of Nowata, Bird Creek, the eastern Osage, and many others. It is safe to say that this sand has provided more than half the oil of the Mid Continent fields and perhaps more oil than any other sand in the world. The Bartlesville Sand occurs in the midst of the dark carbonaceous shales of the Cherokee formation and it has a very wide extent. It is unlikely, however, that the sands thus named in so many of the pools are really one continuous bed of rock, or that they are all exactly at one horizon.

In Kansas the Bartlesville Sand is 100 feet above the Mississippian, but owing to increase in the intervening beds, its distance above the limestone rises as we pass southward in Oklahoma; and around Tulsa, the oil sand is about 450 feet above the Mississippi Lime. The thickness of the Bartlesville Sand, as recorded by the drillers, is sometimes over 100 feet, but it diminishes to northward as we pass into Kansas and soon dies out.

The earliest fields, as before stated, produced abundantly from the sands of the Cherokee Series at a few hundred feet depth. But soon the exploitation was advanced in a westerly direction, where the same oil sands lay at depths of from 1,500 to 2,500 feet.

It is in these deeper fields that the more prolific yield of the Mid Continent Oil Region has been found. The maximum production was still in the sands of the Cherokee Series, but much oil has been obtained also from the sands in higher series, which proved to be productive when encountered at depth. These productive sands are distributed throughout the whole Pennsylvanian column of deposits, the highest being the shallow oil sand of the Newkirk field, which is within two or three hundred feet of the top of the Pennsylvanian.

Geological descriptions of the actual rocks which contain the oil are usually very imperfect because of the incompleteness of the evidence afforded by the ordinary drilling process.

An unusually good account of the main oil sands in the Cushing field, is quoted * below. As these sands in this one field alone have provided about 3% of the world's oil, their character is a matter of importance.

From the drilling in the Cushing field the following details were obtained:

"*Layton Sand* is productive of oil principally in the northern part of the field, in the district south and east of Drumright, and in an area a few miles south of Shamrock. Generally it underlies a hard limestone, 10 to 20 feet thick, called by the drillers 'Layton Lime,' in contrast to the Layton Sand, which is a soft sandstone not fully saturated with oil. The top of the sand is at many places barren and the 'pay' generally lies in streaks, a condition probably due to difference in porosity and to intraformational barriers caused by cross-bedding. The maximum thickness of the sand reported is about 100 feet, and the average of many reports is about 50 feet. The sand is coarse grained, porous, and comparatively soft, and is fairly uniform in texture and porosity. In the Cushing field about 14 square miles of this sand produced oil and 12 square miles originally carried much gas.

"*Jones Sand* produces oil in commercial quantities only in a small area on the south side of the dome in the north part of the field, although it contains a little oil and gas at many other localities. Nearly all the logs examined report a thickness ranging from 15 to 35 feet.

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* U. S. Geological Survey Bull. 658, pp. 14–16.

"*Wheeler Sand* is one of the most uniform in the field, in thickness. It includes the overlying 'Wheeler Lime,' from which it is separated by a shale 'break,' ranging in thickness from 50 to about 100 ft. The lower sandy member is correlated by the drillers with the 'Oswego Lime' of northeastern Oklahoma and southeastern Kansas. It is a coarse-grained, brownish limestone that includes porous or sandy layers which contain the oil. The part below the shake 'break' is more porous than the part above it, and comprises about half the formation. At some places the limestone above the shale 'break' carries gas in commercial quantities, and at others, on the sides of the folds, it carries water.

"The shale 'break' between the two members ranges in thickness from 5 to 25 feet. In the Cushing field about 11 square miles of the Wheeler Sand produced oil, and about 21 square miles produced gas exclusively. The Wheeler Sand, like the Layton and Bartlesville Sands, is not completely saturated.

"*Skinner Sand* lies 250 to 400 feet below the Wheeler Sand and is locally utilized for oil in the northern part of the Cushing field.

"*Bartlesville Sand* is the most productive oil sand in the Cushing field. This 'sand' ranges in thickness from a few inches to about 200 feet, and in porosity from compact brown shale to lenses of porous brown coarse-grained sandstone. In different wells it varies greatly in thickness, texture, and porosity; and in its content of oil, gas, or water. In some wells in the northern part of the field, it attains a thickness of over 200 feet, and one part of the sand may be 'dry,' another part may carry great volumes of gas under tremendous pressure, still another part may furnish great quantities of oil, and others may be filled with salt water. These so-called 'streaks' are probably due to differences in porosity and apparently occur in no regular order, salt water under great pressure being found in some wells above excellent oil 'pay.' Notwithstanding these facts, the sand has been immensely productive, though its yield has not been so great as that which might be expected from a body of sand so thick, for the real 'pay' may form only a small percentage of the total thickness of the sand.

The total oil and gas area in the Bartlesville sand is about 20 square miles, of which but 2 square miles carries gas only.

"*Tucker Sand.* The principal area in which oil is produced from the Tucker sand lies near Drumright and is not large. This sand is uniform in porosity, medium grained, and blue or bluish green, and although its average thickness is perhaps less than that of the Bartlesville, not enough wells have been drilled through it to determine this question. Many of the logs show that the Tucker sand is separated from the Bartlesville sand by a thin bed of green shale."

The following table shows the vertical distribution of the oil in the Pennsylvanian column of Oklahoma. The correlations made by the Oklahoma Geological Survey,* are here adopted.

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* Circular No. 7, by F. Aurin.

Formation	*Sand*	*Blackwell, Kay Co.*	*Billings, Noble Co.*	*Ponca, Kay Co.*	*New-kirk, Kay Co.*	*Yale, Payne Co.*
Garrison	Sand	350*				
	Sand	435*				
	Blackwell	715*	740*	275*		
Eskridge	Sand	920*	1,027*	405*		
Elgin	Sand			550*	450	
	Newkirk		1,476*	925	900	
Buxton	Sand	1,750*				
	Sand	1,800		1,330		
	Ponca		2,033	1,550		
Wilson	Musselman					
	Sand					
Coffeyville	Layton					
Nowata	Jones, Wayside					
Oologah	Big-Lime					
Labette	Cleveland					
	Peru					
Fort Scott	Oswego-Lime, Swenson, Wheeler	3,360				2,720*
Cherokee	Squirrel, Bixler					
	Skinner					2,875*
	Red Fork					
	Sand					
	Bartlesville, Glenn, Gas of Morris			3,625		3,130
	Sand					
	Tucker, Meadows, Burgess, Booch					
	Sand, Second Booch					
	Dutcher, Colbert					
	Mounds					
	Sapulpa, Morris					
	Glenn of Morris					
	Leidecker					
	Muskogee, Boynton					

* Gas, with little or no oil.

Formation	*Sand*	*Cushing, Creek Co.*	*Ranch Creek, Osage Co.*	*Laud-erdale, Pawnee Co.*	*Cleve-land, Pawnee Co.*	*Boston, Creek Co.*	*Osage Junct., Osage Co.*	*Wynona, Nowata Co.*
Garrison	Sand							
	Sand							
	Blackwell							
Eskridge	Sand							
Elgin	Sand							
	Newkirk							
Buston	Sand							
	Sand							
	Ponca							
Wilson	Musselman	700*				450*	485	
	Sand	1,240*			1,000			
Coffeyville	Layton	1,480			1,300	1,240*		
Nowata	Jones, Wayside	1,730*					1,350	
Oologah	Big-Lime							
Labette	Cleveland	1,920*	1,850		1,600			
	Peru							
Fort Scott	Oswego-Lime, Swenson, Wheeler	2,250	2,050			1,800		1,750*
Cherokee	Squirrel, Bixler	2,375*	2,180					
	Skinner	2,620		2,350	2,200			
	Red Fork							
	Sand							
	Bartlesville, Glenn, Gas of Morris	2,700		2,500	2,400			2,100
	Sand			2,654				
	Tucker, Meadows, Burgess, Booch	2,830		2,740	2,700			
	Sand, Second Booch							
	Dutcher, Colbert							
	Mounds							
	Sapulpa, Morris							
	Glenn of Morris							
	Leidecker							
	Muskogee, Boynton							

* Gas with little or no oil.

Formation	*Sand*	*Big-heart, Osage Co.*	*Caney, Washington Co.*	*Canary, Washington Co.*	*Copan, Washington Co.*	*Wann, Washington Co.*	*Dewey-Bartlesville, Washington Co.*
Garrison	Sand						
	Sand						
	Blackwell						
Eskridge	Sand						
Elgin	Sand						
	Newkirk						
Buxton	Sand						
	Sand						
	Ponca						
Wilson	Musselman						
	Sand						
Coffeyville	Layton						
Nowata	Jones, Wayside				700	500	525
Oologah	Big-Lime						
Labette	Cleveland						
	Peru						710
Fort Scott	Oswego Lime, Swenson, Wheeler						
Cherokee	Squirrel, Bixler						
	Skinner						
	Red Fork						
	Sand						
	Bartlesville, Glenn, Gas of Morris	1,680	1,185	1,190	1,350	1,225	1,265
	Sand						
	Tucker, Meadows, Burgess, Booch		1,460*	1,480*	1,550*		1,315*
	Sand, Second Booch						
	Dutcher, Colbert						
	Mounds						
	Sapulpa, Morris						
	Glenn of Morris						
	Leidecker						
	Muskogee, Boynton						

* Gas, with little or no oil.

Formation	*Sand*	*Avant-Ochelata, Osage Co.*	*Hog-shooter, Washington Co.*	*California Creek, Nowata Co.*	*Delaware Childers, Nowata Co.*	*Nowata, Nowata Co.*	*Adair, Nowata Co.*
Garrison	Sand						
	Sand						
	Blackwell						
Eskridge	Sand						
Elgin	Sand						
	Newkirk						
Buxton	Sand						
	Sand						
	Ponca						
Wilson	Musselman						
	Sand						
Coffeyville	Layton						
Nowata	Jones, Wayside						
Oologah	Big-Lime						
Labette	Cleveland						
	Peru		500				
Fort Scott	Oswego Lime, Swenson, Wheeler						
Cherokee	Squirrel, Bixler						
	Skinner		885				
	Red Fork						
	Sand						
	Bartlesville, Glenn, Gas of Morris	1,400	1,085	930	750	640	1,025
	Sand						
	Tucker, Meadows, Burgess, Booch		1,160*	1,030*			
	Sand, Second Booch						
	Dutcher, Colbert						
	Mounds						
	Sapulpa, Morris						
	Glenn of Morris						
	Leidecker						
	Muskogee, Boynton						

* Gas, with little or no oil.

Formation	*Sand*	*Codys Bluff, Nowata Co.*	*Alluwe, Chelsea, Nowata Co.*	*Oologah, Tulsa Co.*	*Collinsville, Tulsa Co.*	*Bird Creek-Flat Rock, Tulsa Co.*	*Owasso, Tulsa Co.*
Garrison	Sand						
	Sand						
	Blackwell						
Eskridge	Sand						
Elgin	Sand						
	Newkirk						
Buxton	Sand						
	Sand						
	Ponca						
Wilson	Musselman						
	Sand						
Coffeyville	Layton						
Nowata	Jones, Wayside						
Oologah	Big-Lime						
Labette	Cleveland						
	Peru						
Fort Scott	Oswego-Lime, Swenson, Wheeler					700*	
Cherokee	Squirrel, Bixler						650*
	Skinner						
	Red Fork						850*
	Sand		400				
	Bartlesville, Glenn, Gas of Morris	525	465		860	1,100	
	Sand						
	Tucker, Meadows, Burgess, Booch	725*		970		1,250	1,200
	Sand, Second Booch Dutcher, Colbert						
	Mounds						
	Sapulpa, Morris						
	Glenn of Morris						
	Leidecker						
	Muskogee, Boynton						

* Gas, with little or no oil.

Formation	*Sand*	*Claremore, Rogers Co.*	*Kellyville, Creek Co.*	*Glenn, Tulsa Co.*	*Red Fork, Tulsa Co.*	*Catoosa, Rogers Co.*	*Inola, Rogers Co.*
Garrison	Sand						
	Sand						
	Blackwell						
Eskridge	Sand						
Elgin	Sand						
	Newkirk						
Buxton	Sand						
	Sand						
	Ponca						
Wilson	Musselman						
	Sand						
Coffeyville	Layton						
Nowata	Jones, Wayside						
Oologah	Big-Lime						
Labette	Cleveland						
	Peru						
Fort Scott	Oswego-Lime, Swenson, Wheeler						
Cherokee	Squirrel, Bixler						
	Skinner			1,050			
	Red Fork			1,400	1,300		
	Sand						
	Bartlesville, Glenn, Gas of Morris	550	1,900	1,500	1,440		540
	Sand			1,650*			
	Tucker, Meadows, Burgess, Booch	700*		1,750	1,650		
	Sand, Second Booch Dutcher, Colbert			1,850		950*	
	Mounds						
	Sapulpa, Morris	9					
	Glenn of Morris						
	Leidecker						
	Muskogee, Boynton						

* Gas, with little or no oil.

Formation	*Sand*	*Broken Arrow, Tulsa Co.*	*Bixby, Tulsa Co.*	*Wicey, Tulsa Co.*	*Coweta, Wagoner Co.*	*Wagoner, Wagoner Co.*	*Stone Bluff, Wagoner Co.*	*Preston, Okmulgee Co.*
Garrison	Sand							
	Sand							
	Blackwell							
Eskridge	Sand							
Elgin	Sand							
	Newkirk							
Buxton	Sand							
	Sand							
	Ponca							
Wilson	Musselman							
	Sand							
Coffeyville	Layton							
Nowata	Jones, Wayside							
Oologah	Big-Lime							
Labette	Cleveland							
	Peru							
Fort Scott	Oswego-Lime, Swenson, Wheeler							
Cherokee	Squirrel, Bixler							
	Skinner							
	Red Fork			1,000				
	Sand							
	Bartlesville, Glenn, Gas of Morris				1,050			1,385
	Sand							
	Tucker, Meadows, Burgess, Booch	1,340	1,225*	1,660				
	Sand, Second Booch		1,300		1,480	700	1,200	1,743
	Dutcher, Colbert							
	Mounds		1,600*					2,020
	Sapulpa, Morris		1,690					
	Glenn of Morris		1,750*					
	Leidecker							
	Muskogee, Boynton							

* Gas, with little or no oil.

Formation	*Sand*	*Okmulgee, Okmulgee Co.*	*Henrietta-Schulter Okmulgee Co.*	*Morris, Okmulgee Co.*	*Booch, Okmulgee Co.*	*Boynton Muskogee Co.*	*Muskogee, Muskogee Co.*
Garrison	Sand						
	Sand						
	Blackwell						
Eskridge	Sand						
Elgin	Sand						
	Newkirk						
Buxton	Sand						
	Sand						
	Ponca						
Wilson	Musselman						
	Sand						
Coffeyville	Layton						
Nowata	Jones, Wayside						
Oologah	Big-Lime						
Labette	Cleveland						
	Peru						
Fort Scott	Oswego-Lime, Swenson, Wheeler						
Cherokee	Squirrel, Bixler						
	Skinner						
	Red Fork						
	Sand						
	Bartlesville, Glenn, Gas of Morris						
	Sand						
	Tucker, Meadows, Burgess, Booch		1,200	1,100	1,200	850*	
	Sand, Second Booch	1,870		1,220	1,330		
	Dutcher, Colbert		1,500				
	Mounds						
	Sapulpa, Morris		1,800	1,620			
	Glenn of Morris			1,720			
	Leidecker					1,400	
	Muskogee, Boynton			1,960*		1,540	1,050

* Gas, with little or no oil.

OILFIELDS OF OKLAHOMA PRODUCING FROM THE PENNSYLVANIAN

The following notes, in small type, relating to individual oilfields, are gathered from many sources. The more recent items are from the various oil journals.

Glen Oilfield (Creek County)

The Glen field occupies the northeast part of Creek County near Sapulpa, and the adjoining parts of Tulsa County, south of Tulsa.

The rocks at the surface belong to the Pennsylvanian System, some 2,300 feet above the Mississippi Lime, or 1,000 feet above the Fort Scott Limestone.

The following are the oil sands:

Sand	*Depth*	*Thickness*	*Remarks*
Sand	760–800	50	Small producer, over a small area. Possibly in the Oologah formation.
Sand	975–1, 00		Small producer.
Sand	1,035	30	Small producer.
Sand	1,075	20	Small producer.
Sand	1,150	25	Small producer.
Red Fork	1,275–1,500	10–30	Important producer.
Sand	1,600–1,650	25	Small producer at some localities.
Glen	1,700–1,790	90	Great producer, may be Bartlesville Sand.
Squaw or Taneha	1,900	10–50	Good producer.
Rhodes or Dutcher	2,000–2,025		Fair producer, about 50 ft. above Morrow Limestone.
Mounds	2,390		Small producer.
Sand	2,530		Small producer, is in the Fayetteville Shale.

The structure in the field, as revealed by the outcrops, has been studied in detail. The contours are somewhat "wavy," but no pronounced folds occur. The beds are dipping westward at 50–60 feet per mile. (See Part VII.)

The oil was discovered in 1906. Development was rapid and the pool soon became the world's most prominent producer.

From March, 1907, to May, 1911, the output was from 1 to 2½ million barrels per month, the maximum being reached in October, 1907. Many of the wells gave 1,000–2,000 barrels a day. In 1909 the number of wells completed was 462, and their average initial yield was 117.7 barrels a day.

This oilfield is now in its decline, but there is still an output of nearly ½ a million barrels a month.

Up to the end of 1919, the Glen field has yielded about 153 million barrels of oil from an area of 30 square miles. Thus the average yield per acre is 8,000 barrels: but in some large parts of the field the figure exceeds 16,000.

Gas in great quantity was found above, below and within the oil sands; and an immense amount was wasted. It is estimated that 4% of the wells were gas wells, many of which had capacity 20–30 million cubic feet a day; and some attained to 70 million.

At present this field is the chief producer of low pressure gas, used for making natural gas gasoline.

Cushing Oilfield (Creek County)

This great oilfield occupies an elongated area in the northwest part of Creek County, along the county boundary. A small part of it is across the county line in Payne County. The town of Cushing, in Payne County, is 10 miles west of the field.

The surface is formed by the highest part of the Pennsylvanian. Between the eastern and western limits of the field some 400 feet of strata crop out, including the Neva Limestone, the Elmdale and some underlying formations. The most prominent bed is the Pawhuska Limestone (about 140 feet above Elgin Sandstone), which forms bluffs in the east part of the field. This has been used as an index horizon for structure mapping.

The geological column in this district, according to F. Buttram,* is as follows:

Neva Limestone.
Sandstone, shales and thin limestone, 556.5 feet.

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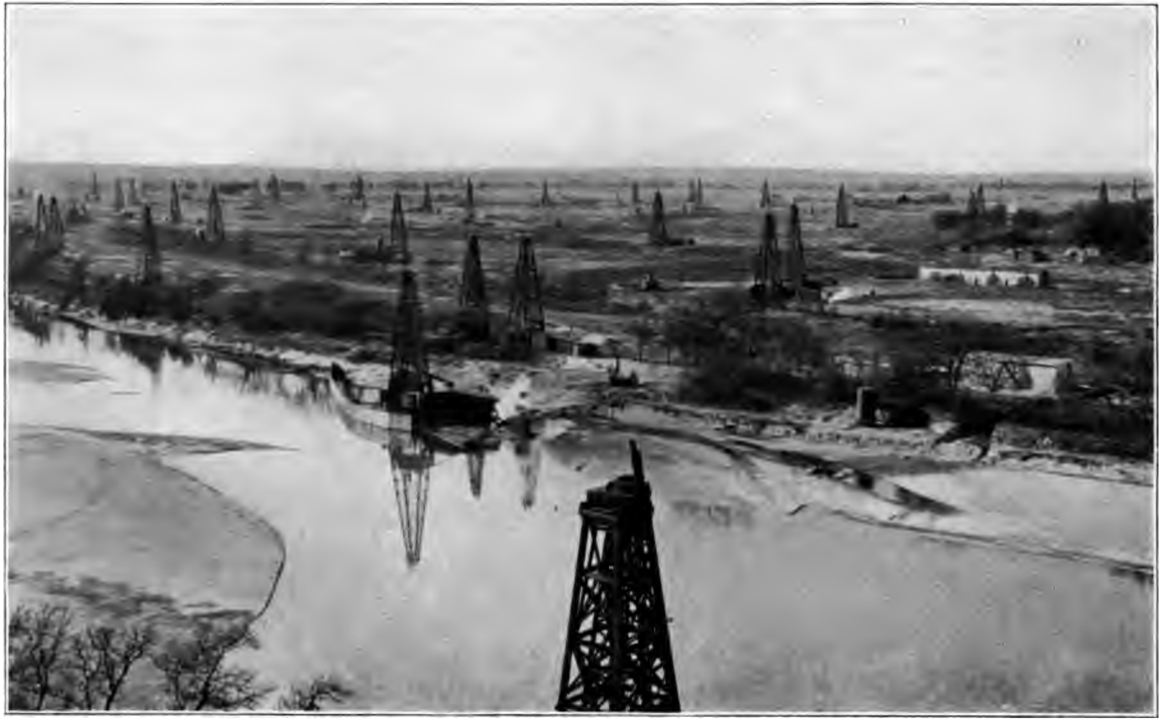
* Oklahoma Geol. Surv., Bull. No. 18.



View No. 6. A part of the Cushing Oilfield.

(*Photograph lent by Mr. A. E. Fath.*)

Pawhuska Limestone (2,340 feet above Fort Scott Limestone).
Shales and Sandstone, 134 feet.
Elgin Sandstone.
Interval.
Lost City Limestone.
Interval, 1,078–1,097 feet; including the Layton Sand and the Wheeler Sand, separated by 700–810 feet.
Fort Scott or Oswego Limestone, 75 feet; including Wheeler Sand.
Interval.
Bartlesville Sand (in Cherokee Shale).

The field is of considerable extent, and within it there is appreciable variation in the thickness of some of the formations. Hence the interval between the sands varies from place to place, and the depth to any given sand may vary by 200 feet or more.

The following is a list of the well-known productive sands. (In some parts of the field the depths may be as much as 100 feet more, or 100 feet less, than the figure here given.)

Sand	*Production*	*Thickness*	*Depth*	*Horizon*
Mussleman	Some gas	25	620	Buxton
Layton	Much oil & considerable gas	50	1,400	Coffeyville
Jones	Some oil	30	1,600	Bandera
Cleveland	Some gas	20	1,700	Labette
Wheeler	Considerable oil & much gas	75	2,200	Fort Scott
Skinner	Some oil	20	2,455	Cherokee
Bartlesville	Very much oil & considerable gas	100	2,600	Cherokee
Tucker	Some oil	30	2,750	Cherokee
New Deep Sand	Some oil		3,020	Cherokee

NOTE.—These depths are from the ground surface, which is about 80 feet below the position of the Pawhuska Limestone.

The bulk of the production came from three of these sands,—the Layton, the Wheeler, and the Bartlesville. The Layton Sand ranges in depth from 1,200 to 1,500 feet, and is 20–100 feet thick.

Approximately 14 square miles of this sand produces oil and 12 square miles carried much gas.

The Wheeler Sand which lies 600 to 900 feet below the Layton, varies in thickness from 50 to 100 feet and its lower sandy member is generally considered to be the equivalent of the Oswego Lime (Fort Scott Limestone) of the country further northeast. About 11 square miles of this sand contained oil and 21 square miles produced only gas.

The Bartlesville Sand, which lies 350 to 550 feet below the Wheeler, is by far the most productive. The maximum thickness is 200 feet. Its productive area is 20 square miles, of which only 2 square miles carried gas alone.

The Cushing oilfield is located on pronouned anticlinal and dome structures which are described in Part VII. They lie along one general north and south line of folding. In order from north to south the principal structural features are:

The Dropright Dome.
The Drumright Dome.
The Wheeler Terrace.
The Mount Pleasant Dome.
The Shamrock Dome (north).
The Shamrock Dome (south).

The productive area is continuous over all these structures from north to south, a distance of 15 miles.

The Cushing oilfield was discovered in March, 1912, but the early production was only from the Wheeler and Layton sands. In December, 1913, the oil in the Bartlesville sand was found and an extremely rapid development ensued. Many of the wells in this sand gave 10,000 barrels a day. The climax was reached in April, 1915, during which month the daily output averaged 300,000 barrels.

A sharp decline followed and the yield is now (1919) 37,000 barrels a day. There are about 2,500 producing wells. The specific gravity of the oil averages .819 (40.90 Be).

Some parts of the field have yielded 20,000 barrels per acre, but the average figure for the whole area is 11,000.

Altogether up to the end of 1919, this oilfield, with an area of 32 square miles, has produced about 236 million barrels of oil, which is about 3% of all the oil which the whole earth has yet provided.

The Cushing field is also one of the chief gasfields in the world. All the sands contain gas in some parts of the field, and many of the gas wells had great capacity. Thus in 1914, 36 wells had a combined initial daily capacity of 608 million cubic feet, and in 1916 the new gas wells had 1,000 million cubic feet initial daily capacity. The pressure varied up to 900 lbs. according to the depth of the sand.

The waste of gas in this field was very large. It was estimated by the Bureau of Mines at over 250,000 million cubic feet, whose fuel value is equivalent to 10 million tons of coal.

Kelleyville Oilfield (Creek County)

In the eastern part of Creek County, west of the Glen field, two small pools of oil have been developed around Kelleyville. The better wells make 200–400 barrels a day.

The daily output in 1915 was about 1,450 barrels a day and at the end of 1918 about 1,250 barrels. Several good wells were brought in during 1919, at 2,500–2,600 feet.

New York Oilfield (Creek County)

A small pool was discovered in 1915 in the east part of Creek County, south of Kelleyville and the Glen field. Some of the wells have given 100 barrels a day.

Bristow Oilfield (Creek County)

South of Bristow in the south central part of Creek County, some small gas-wells and a few oil wells have been drilled. Some production was found at over 3,000 feet.

Garber Oilfield (Garfield County)

This oilfield is near the east edge of Garfield County, 10 miles southwest of the Billings field. The Permian red rocks are at the surface. The wells are on a well-defined dome. (See Part VII.)

The Garber field is notable for the number of its sands. Production is being obtained from 11 different horizons, of which four are important.

Part of the field has now been drilled over three times and there are three wells per location.

The principal sands are:

Hoy Sand	at 900 feet.
Hotson Sand	at 1,500 feet.
Belveal Sand	at 1,750 feet.
Garber (Billings) Sand	at 2,100 feet.

During 1919 some production has been found at 2,300 feet and at 2,700 feet.

The exploitation began in 1916, and a hundred-barrel well was brought in at 1,100 feet. Much drilling ensued and many good wells were obtained. The initial yield of the better wells ranges from 300 to 2,000 barrels a day. During the second half of 1917 the output averaged 2,000 barrels a day. By the end of 1918 there were 135 wells, and in the latter part of 1919, the output was 9,000–10,000 barrels a day.

Haskell Oilfield (Haskell County)

This small new oilfield is 7½ miles southwest of the town of Haskell. It is situated at the southeast corner of the proven oil territory of Oklahoma.

The main oilsand lies at a depth of 1790 feet. A number of the wells have come in at 500–1,000 barrels a day.

The field was opened during 1919, and still is in the early stages of development.

Ponca City Oil and Gasfield (Kay County)

This field is in the southeast corner of Kay County, extending southwest of Ponca.

The surface is occupied by Lower Permian beds, of which the Herrington Limestone (55 feet above the Winfield Limestone) is most conspicuous and has been used as the datum horizon for structure mapping.

The wells are situated on a long and narrow dome structure which is further mentioned in Part VII.

There are a number of productive sands in this field. The principal gas sand lies at about 550 feet below the Herrington Limestone. Its thickness is 25–50 feet. Most of the early wells were drilled no further than this sand, their capacities ranging from 5–7 million cubic feet. Oil was produced from sands at 975, 1,330 and 1,550 feet, the last one being the most important. Some wells had an initial yield of several hundred barrels a day. The sand at 975 feet is probably the Elgin Sand. More recently deeper drilling has led to the discovery of oil sands and other gas-sands at various depths down to 2,600 feet.

During 1919 an important deep sand was found at 3,900 feet. Several of the wells have come in at 1,000–3,000 barrels a day.

The development of the field commenced in 1905 and a large amount of gas was marketed in 1906–1908.

The first important oil well was obtained in June, 1911; and in 1912 there were 30 wells producing oil, and averaging 34 barrels a day per well. In 1916 the output was about 600 barrels a day, and at the end of 1918 it was 580 barrels. During 1919 the production has been increased to about 2,500 barrels a day.

The oil has specific gravity .79–.81.

Newkirk Gasfield (Kay County)

This small gasfield is situated at the town of Newkirk in the north-central part of Kay County. (A more important productive area, 6 miles southeast of Newkirk, is now referred to as the Mervine field.)

The surface rocks belong to the lower part of the Permian. The depth of the wells at Newkirk was from 600 to 2,200 feet and their capacities were generally less than ¼ million cubic feet a day.

The development commenced in 1905.

Mervine Oilfield (Kay County)

This field is in the east-central part of Kay County, north of Ponca, and 6 miles E. S. E. of Newkirk.

The rocks at the surface belong to the lower part of the Permian. There are conspicuous outcrops of the Herrington Limestone.

The wells are situated on a narrow elongated dome structure. (See Part VII.)

The production until recently was from a sand at 900 feet, considered to be the Elgin Sandstone, which was reached at 975 feet in the Ponca field. Some of the wells in this sand came in at 100–500 barrels a day.

Important production of oil and gas is now being obtained from deeper sands, notably at 3,100 feet. Some of these deeper wells have an initial daily yield of over 1,000 barrels, and some wells give 30–40 million cubic feet of gas per day.

The drilling on this dome was commenced in 1913, after the structure had been mapped by the Oklahoma State Geological Survey.

The first well was brought in as a 100-barrel producer in the 900-foot sand. In April, 1914, the field had an output of 2,500 barrels a day. In 1918 there was much development in the deep sands, and in May, 1919, the daily production had reached 4,300 barrels, but has since declined to 1,500 barrels.

Blackwell Oilfield (Kay County)

This oil and gasfield is in the northwest quarter of Kay County, extending from Blackwell northward 14 miles to the Kansas border.

The shales and thin limestones which crop out at the surface belong to the lower part of the marine Permian deposits. The wells are mainly on the west side of an irregular anticlinal structure. (See Part VII.)

The succession of oil and gas sands does not seem to be the same in all parts of the field. The number of gas sands is quite remarkable and the wells are phenomenal producers. (See Part VIII.) In one well, down to 3,200 feet, eight separate sands were found, each yielding from 1 to 30 million cubic feet per day, and with a combined capacity estimated at 116 million cubic feet.

The oil production has been obtained first from a deep sand at 3,300–3,400 feet, and more recently from a sand at 1,800 feet.

The Blackwell field was developed first for gas. The drilling commenced in 1904–1905, and there were 21 producers in February, 1912. These earlier wells produced chiefly from a sand at

750 feet, and had capacities up to 5 million cubic feet. Deeper drilling followed and a much greater quantity of gas was obtained.

The first oil well of importance was drilled in 1914 and came in at 600 barrels a day, in a sand at 3,360 feet. Many deep wells were then drilled and some of them had initial production of several thousand barrels a day.

Near the close of 1916 there was a yield of 4,000 barrels a day and in October, 1917, the production had increased to 10,000 barrels a day, chiefly from the deep sand at 3,300–3,400 feet.

During 1918 better results were obtained from a sand at 1,800 feet, from which the present output is mainly derived. At the end of the year there were 275–300 producing wells, and in May, 1919, the output was 5,500 barrels a day.

Large plants for the extraction of gasoline from the natural gas are now in operation.

Muskogee-Creekola Oilfield (Muskogee County)

This oilfield extends southwestward from the town of Muskogee in the north part of the county. The producing territory is continuous for six or seven miles as far as Creekola and beyond.

The beds exposed at the surface are about the horizon of the Fort Scott Limestone. The logs of the wells show that there is a large thickness of shale and sands before the Mississippian Limestone is reached. Presumably the Morrow and Winslow formations are thicker here than at their outcrops to the northeast.

In the older part of the field, at the town, the production is from the Muskogee Sand at 1,050 feet, which is supposed to be near the base of the Cherokee formation.

The main production now is from the southwest part of the field, near Creekola. The sands lie at 1,400–1,700 feet.

The first developments in this field were in 1894, but only a small amount of oil was obtained. In 1904 some 40 wells were drilled on the present townsite, all of which were small producers of a high grade oil. In 1906, extension southwestward towards Creekola commenced. In 1910, 171 wells were drilled and the average initial yield was 135 barrels a day. About one-third of the wells are gas wells. In 1913 the Muskogee district produced over 420,000 barrels of oil, but since then there has been a sharp decline and the output at the end of 1918 was less than 200 barrels a day.

Boynton Oilfield (Muskogee County)

This field is in the southwest part of Muskogee County, near the town of Boynton.

The outcropping formations belong to the middle part of the Pennsylvanian.

Good gas sands were reported at 825, 1,100 and 1,400 feet and some of the wells had capacity up to 5 million cubic feet a day. The Boynton Sand, at 1,500–1,600 feet, was the chief oil producer.

The field was discovered early in 1914, and by the end of that year 10,000 barrels of oil had been obtained. In 1915 the production reached 7,500 barrels a day, but at the end of 1919, it had declined to a daily output of less than 2,000 barrels.

Billings Oilfield (Noble County)

This field is in the northwest corner of Noble County, east and south of Billings.

The surface is occupied by the red rocks of the Permian.

The wells are situated on an anticlinal structure.

There are several sands containing oil and gas, but the oil production is almost wholly from the Billings Sand at 2,100 feet. Some of the wells have come in at 2,000 or 3,000 barrels a day; and there are gas wells of good capacity.

The exploitation commenced in 1910, but it was not until 1917 that any important quantity of oil was obtained. At the close of that year the output was about 1,700 barrels a day. During 1918 the production rose to 15,000 barrels a day, but by the end of 1919, it had declined to 2,200.

Nowata or Clagett Oilfield (Nowata County)

The area occupied by this field consists of some 8 square miles on the north and northeast side of Nowata. It may be regarded as a western extension of the Coody's Bluff pool.

The rocks outcropping at the surface include the Oologah formation, the Lenapah Limestone and intervening beds.

The principal oil horizon is the Bartlesville oil sand which is about 18 feet thick. The depths of the wells vary from 550 to 750 feet.

The initial production of the wells generally was rather small, but as recently as April, 1919, a well was brought in at 250 barrels a day. The field contained some 700 wells but is now largely exhausted. The output of the Nowata district in the latter part of 1919, was 3,800 barrels a day.

Adair Oilfield (Nowata County)

This field lies about 6 miles west of the town of Nowata.

The surface in this district is occupied by the upper part of the Coffeyville formation.

The wells encounter the Fort Scott Limestone at 625 feet. The Bartlesville Sand, which is about 35–50 feet thick, is reached at 1,025 feet.

The pool was discovered in 1911 and was rapidly developed in 1912 and 1913. Most of the wells have been small producers, averaging about 20 barrels a day initial yield, but some of the earliest wells came in at 400 barrels a day.

Delaware-Childers Oilfield (Nowata County)

This large oilfield extends in a W. N. W. direction across the central part of Nowata County for a distance of 14 miles.

In the western part of the field the wells stand on the Nowata Shales, while at the east end the Pawnee Limestone is at the surface.

The production is obtained mainly from the Bartlesville Sand which lies at a depth of 700–850 feet, and is 50 feet thick. Many of the early wells had initial production of 100–150 barrels a day. Some good gas wells also were obtained.

The active development commenced in 1908; and in the period 1908–1912, 2,189 wells were completed. The field is now much exhausted.

In the latter part of 1919, the output of the Delaware district was 1,100 barrels a day.

California Creek Oilfield (Nowata County)

This small field covers about 3 square miles at the north edge of the county, adjoining Kansas, 5 miles south of Coffeyville.

Productive sands are reported at 220, 515, 1,020, and 1,145 feet. None of these have been identified as the Bartlesville Sand.

The drilling commenced in 1911, and before the close of 1912, 25 gas-wells had been obtained with total daily capacity of 85 million cubic feet. The amount of oil produced is comparatively small.

Coody's Bluff-Alluwe-Chelsea Oilfield (Nowata and Rogers Counties)

This large oilfield occupies a large part of southeast quarter of Nowata County and extends southward several miles into Rogers County. In the north part is Coodys Bluff; in the center Alluwe; and to eastward of the south end is the town of Chelsea. The length is 18 miles and the area about 75 square miles.

The Fort Scott Limestone is at the surface in the south part of the field, and beds 300 feet higher are exposed at the north end.

The field is on an anticline which pitches downward towards the north. The wells are shallow, and yield an oil of spec. grav. .85.

The productive sands are:

Bartlesville Sand	20 ft. thick	depth, 400–600 ft.
Burgess Sand	15 ft. thick	depth, 465–800 ft.

The field was opened in 1904; and in 1906 the daily production reached a maximum of about 53,000 barrels. In 1906 the number of wells completed was 1,390; and their average initial yield was 33 barrels a day.

Since that date the activity declined, but has been revived somewhat during the past four years. Altogether, probably more than 8,000 wells have been drilled. The output of the Chelsea district during 1919, was 1,200 a day.

Beggs Oilfield (Okmulgee County)

The Beggs pool is in the north central part of Okmulgee County, south of the town of Beggs.

The outcropping strata are the Cottonwood Limestone and the immediately overlying beds.

The early wells produced from sands at 1,700, 2,048 and 2,500 feet. Afterwards various productive sands between 2,000 and 2,900 feet were found. Much oil was obtained from the Dutcher Sand, at 2,300–2,400 feet. Recently a promising new pool has been opened in a sand at 2,900 feet, which is said to be within the Mississippi Lime. A number of the new wells have an initial production of 1,000–3,000 barrels a day.

Active development commenced after the discovery of the Preston pool in 1909. In 1910 and 1911 about 44 wells were drilled, some of them flowing 1,000 barrels a day or more. After this the field rapidly declined and in 1914 there were only a few small pumping wells.

Activity was renewed in this district in 1916–1918 and good wells were drilled in the deeper sands, producing 1,000–1,500 barrels a day. During 1919 there has been much drilling, and the discovery of the new sand, in the Mississippi Lime, has increased the output considerably.

In the latter part of 1919 the output of the Beggs district (including Youngstown and Hamilton Switch) was stated to exceed 40,000 barrels a day.

Youngstown Oilfield (Okmulgee County)

This oilfield occupies a few square miles of territory lying about 6 miles south of the Beggs pool, near the west border of Okmulgee County.

The strata at the surface in this district belong to the top part of the Pennsylvanian and the bottom part of the Permian.

The oil is found chiefly in the Wilcox Sand at 2,300–2,400 feet. Production has been obtained also at 2,700–2,750 feet, and at 3,000–3,050 feet.

The important development took place in 1918, when many wells in the Wilcox Sand came in at 500–1,000 barrels a day.

Recently, during the first half of 1919 several good wells have been obtained in the deeper sands. In January, 1919, there was an output of 6,000 barrels a day.

Bald Hill Oilfield (Okmulgee County)

This field occupies the east central part of Okmulgee County, east and northeast of the town of Okmulgee. It extends northeastward also into a small part of Muskogee County.

The rocks at the surface are lower Pennsylvanian about the horizon of the Fort Scott Limestone. The production is from the Cherokee Series.

A number of sands have produced in this field. The most important occur at depths of 1,300–1,700 feet. Deeper sands also were reported below 2,000 feet.

A few of the wells came in at 300–500 barrels a day, but the majority gave 20–100 barrels a day. There were also gas wells with daily capacity up to 5 million cubic feet.

The drilling commenced in 1907. In 1913 there was much development and there was an output of 1,847,790 barrels. During 1914 the results were still greater; but in 1915 and 1916, although many wells were drilled, about half of them were not successful. The output at the close of 1919 was about 4,000 barrels a day.

The Booch Sand area adjoins this field and should be considered as a part of it. In it, some of the wells yielded 1,000–3,000 barrels a day at 1,200–1,500 feet.

Booch Oilfield (Okmulgee County)

The Booch Sand area is in the east part of Okmulgee County adjoining the older Bald Hill pool on the south. It is really a part of the Bald Hill field.

The surface rocks are near the Fort Scott horizon.

Production has been obtained from at least six sands, belonging to the Cherokee formation, the principal ones being:

Booch Sand	at 1,200 feet.
Second Booch Sand	at 1,325 "
Morris Sand	at 1,560 "
Glenn Sand	at 1,660 "

A number of the wells have been large producers, coming in at 1,000–3,000 barrels a day.

In May, 1914, the output was about 22,000 barrels. There has been considerable development in the past three years.

The daily yield of the Bald Hill and Booch fields, in the latter part of 1919, was less than 4,000 barrels.

Morris Oilfield (Okmulgee County)

This field occupies some 10 square miles in the southeast part of the county, south and southeast of the town of Morris.

The surface rocks belong to the lower part of the Pennsylvanian, near the horizon of the Fort Scott Limestone. The oil is obtained from the Cherokee formation.

There are five or more productive sands, chiefly at depths 1,500–2,000 feet. The Booch Sand lies at 1,100–1,200 feet. The average initial yield of the early wells was 150 barrels a day. There is a deep sand from which some wells have given several hundred barrels a day.

Development has been more or less continuous since 1906 and several hundred wells have been drilled.

In 1907 the output was 800 barrels a day and in 1910 this had increased to 8,000. During 1919, the production was about 2,000 barrels a day.

Tiger Flats Oilfield (Okmulgee County)

This small field is in the southwest part of Okmulgee County, 6 miles southwest of Okmulgee.

The rocks at the surface belong to the lower portion of the Pennsylvanian, above the Fort Scott Limestone horizon.

There are several productive oil sands. A good yield has been obtained at 1,500 feet, 2,150 feet, and 2,300 feet. Many of the early wells gave several hundred barrels of oil a day. Good gas wells also were obtained.

The pool was discovered in 1913. The output in May, 1919, was 4,500 barrels a day.

Mounds Oilfield (Okmulgee County)

This oilfield lies immediately south of the Glen pool. It is partly in Okmulgee County at the north boundary, and also partly in Tulsa County and Creek County, around the town of Mounds.

There are productive oil sands and gas sands at several horizons down to a depth of 2,200 feet.

Most of the wells are small producers and only a few of them attain to 100 barrels a day.

At the end of 1917 the output was about 1,400 barrels a day, and in the latter part of 1919 it was 1,700 barrels a day.

Henryetta-Schulter Oilfield (Okmulgee County)

This oilfield is in the south of Okmulgee County. It lies 4 miles northeast of Henryetta and extends from Schulter in a southeast direction for 7 miles.

The surface rocks belong to the middle part of the Pennsylvanian and the depth to the oil is 1,200–1,800 feet. Several wells came in at 1,000–2,000 barrels a day, but more generally the initial yield was 100–500 barrels.

The field was discovered in 1910 when a 600-barrel well was drilled, followed by a gas well reported to have a capacity of 80 million cubic feet a day.

The principal development was in 1912 and 1913 when 471 wells were completed.

The output during 1919, was 1,000–2,000 barrels a day.

Preston (or **Hamilton Switch**) **Oilfield** (Okmulgee County)

This field occupies a small area in the west-central part of the county, 5 miles northwest of Okmulgee.

The rocks exposed at the surface belong to horizons near the middle of the Pennsylvanian.

Oil has been produced from some eight different sands, at depths from 1,100 feet to 2,050 feet. Some of the early wells gave 1,000 barrels a day. There were also gas wells of capacity 35–40 million cubic feet.

The opening up of the pool took place in 1909; and in 1910 about 100 wells were drilled. In the years 1909–1914, some 600 wells were completed of which three-quarters were productive and one-quarter were dry. In this period, however, the average initial yield per well was high, being 287.5 barrels a day in 1909 and 100 barrels a day in 1914. The daily output of the field at the close of 1918 was 900 barrels.

Hominy Oilfield (Osage County)

This small oilfield is in the south-central part of Osage County, 5 miles northwest of Hominy.

The oil is obtained from the Cleveland Sand and the Bartlesville Sand, and from the Mississippi Lime.

This pool was opened in 1916 and development is still in process. The production from the Mississippi Lime has been opened up during 1919 at depth 2,300–2,800 feet. Some of the wells came in at several hundred barrels a day.

Boston Oilfield (Osage County)

This small field is situated at the south border of Osage County, three miles northwest of Cleveland. It is really a northwest extension of the Cleveland field.

The Cleveland Sand lies at a depth of 1,800 feet.

The wells in this pool have been very productive. Many of them came in at 500–1,500 barrels a day.

Wynona Oilfield (Osage County)

This field is in the east-central part of Osage County, southeast of Wynona.

The oil comes mainly from the Bartlesville Sand. The Cleveland Sand also is productive.

During 1919 a number of good wells have been obtained, with initial production 500–2,000 barrels a day from a depth of 2,000–2,300 feet.

Avant-Ochelata Oilfield (Osage County and Washington County)

This oilfield is practically a southern extension of the Bartlesville field. It occupies a narrow strip of territory along the middle part of the east border of Osage County. Part of the field lies across the boundary in Washington County near Ochelata and also west of Ramona.

The rocks at the surface are about the horizon of the Avant Limestone in the Wilson formation.

The conditions are stated to be very similar to those of the Bartlesville field, but the sands lie rather deeper. The depth of the wells was generally 1,500–1,600 feet.

Cleveland and Osage Junction Oilfield (Pawnee County)

This large oilfield occupies some 50 square miles at the east end of Pawnee County.

The rocks at the surface belong to the top part of the Pennsylvanian, about the horizon of the Elgin Sandstone.

Production has been obtained from a number of sands; at first principally from the Cleveland Sand, about 1,500 feet above the top of the Cherokee, but afterwards largely from the Bartlesville.

Sand	*Depth*
Sand	500
Sand	1,000
Layton Sand	1,300
Sand	1,400–1,500
Cleveland Sand, (500 ft. above Fort Scott Limestone)	1,570–1,700
Skinner Sand	2,200
Bartlesville Sand	2,400
Tucker or Meadows Sand	2,600–2,800

The depths differ in different parts of the field, and not all the above sands are productive at the same place.

At first the output was mainly from the Cleveland Sand at 1,700–1,800 feet (about 500 feet above the top of the Cherokee formation), but in subsequent years there was deeper drilling, and a large production was obtained from the Bartlesville Sand.

Drilling in the Cleveland district was in progress during 1904, and in September of that year the first good well was brought in. Great activity resulted, and many wells were drilled close together on the town lots. Most of the early wells gave an initial yield of 25–300 barrels a day, from a depth of 1,800 feet.

In 1907 the Cleveland field had an output of 2,000 barrels a day and in 1910 the daily output was 3,000 barrels.

In 1911 there was renewed development and 165 wells were completed. Some of these wells came in at 1,000 barrels, the average initial production being 171 barrels a day.

The production at the end of 1917 was about 6,800 barrels a day, and in the latter part of 1919, about 5,200 barrels a day.

Yale-Quay Oilfield (Payne County)

A small but important oilfield has been developed recently at the east end of Payne County. The field extends northward from Yale to beyond Quay in Pawnee County.

The rocks at the surface are the top members of the Pennsylvanian. The field is on a well-marked anticline.

Several productive sands occur at depths between 2,700 and 3,500 feet.

The first oil well was drilled in 1914 and came in at 250 barrels a day, at a depth of 3,145 feet. Many good wells were obtained during 1917 and 1918, some of them flowing several hundred barrels a day. The gas wells have capacities up to 20 million cubic feet a day with a pressure of 1,100 pounds. During 1919 some good production has been opened up in the Mississippi Lime at 3,500 feet. The wells commence at 100–800 barrels a day.

The daily production of the field, at the end of 1917 was about 14,000 barrels a day. Since then there has been some decline and in the latter part of 1919, the figure was 9,500 barrels a day.

Catoosa Gasfield (Rogers County and Wagoner County)

This field occupies a small area in the southwest corner of Rogers County and the northwest corner of Wagoner County.

The rocks at the surface belong to the lower part of the Pennsylvanian. The principal gas sand lies at about 950 feet and probably is near the top of the Mississippi Lime.

The capacity of the wells is from 3 to 15 million cubic feet a day.

Claremore Gasfield (Rogers County)

This small field is in the middle of Rogers County, 2 miles east and southeast of Claremore.

The rocks at the surface belong to the lower part of the Pennsylvanian. The productive sand lies at a depth of 810–815 feet, and probably is not far above the Mississippian Limestone.

The wells have capacity 1–7 million cubic feet a day; and the initial pressure was about 400 pounds.

There was some extension of this field during 1916, with fairly good results.

Inola Oilfield (Rogers County)

This field is in the southeast corner of Rogers County, a few miles west of Inola.

The outcropping beds belong to the lower part of the Pennsylvanian. The productive sands lie at 500 feet (probably the Tucker Sand), and at 670 feet.

Many of the early wells gave 150–300 barrels a day, and in 1914 there were two 1,000-barrel wells in the 500-foot sand. In 1919, the production was about 300 barrels a day.

Collinsville-Owasso-Dawson Field (Tulsa County and Rogers County)

This oil and gasfield occupies some twenty-five square miles in the north part of Tulsa County and the west edge of Rogers County. It extends southwestward from around Collinsville for 14 miles to Dawson, within three or four miles of Tulsa.

The rocks which are near the surface belong to the middle part of the Pennsylvanian. In the center of the field the Mississippi Lime lies at a depth of 1,100–1,200 feet, and the oil and gas is found in various sands above. The field is more noted for its gas than for oil. Many large gas wells were brought in and much of the gas was used at the zinc smelters in Collinsville.

Red Fork—Broken Arrow—Jenks Oilfield (Tulsa County)

This oilfield, in the east-central part of Tulsa County, occupies the territory between Tulsa and the Glen field. It is practically continuous with the north part of the Glen field.

The earliest wells in Tulsa County were drilled around Red Fork. The field was opened in 1901, and before the close of 1904 there were 50 producing wells.

The wells at Red Fork were small producers but were long lived. Some of those at Jenks were reported to yield as much as 300 barrels a day. The production of the Red Fork wells is now only a few hundred barrels a day, but the daily output of the Jenks-Broken Arrow pool was about 1,500 barrels a day in the latter part of 1919.

Bird Creek—Flat Rock Oilfield (Tulsa County)

This field is spread over some 50 square miles, along the west edge of the north half of Tulsa County. It extends for 15 miles S. S. E. from Skiatook, in the northwest corner of the county, to within three or four miles of Tulsa and Dawson.

The rocks at the surface belong to the middle part of the Pennsylvanian. Most of the wells start at a horizon not far from the Lenapah Limestone. The production came chiefly from the Bartlesville Sand at about 1,200 feet.

This oilfield was one of the early developments in the State. Considerably over 1,000 oil wells were drilled and many of them came in at several hundred barrels a day. Good gas wells also were obtained. During 1919 the output from the Bird Creek field was about 6,000 barrels a day.

Bixby Oilfield (Tulsa County)

This small but highly productive field is situated near the southwest corner of Tulsa County, about 4 miles southwest of Bixby.

The oil is found at 1,600–2,100 feet. Many of the wells have come in at 400–800 barrels a day, the average initial yield in the first year being probably about 200 barrels.

The development of this field has taken place during the past 5 years and good wells are still being drilled. In 1915 the output was 1,600 barrels a day. During 1919, the daily yield of the Bixby and Leonard pools was 3,000 barrels.

Wagoner Oilfield (Wagoner County)

Four miles northwest of the town of Wagoner there is a small oilfield near the north border of the county.

The surface beds belong to the lower part of the Pennsylvanian. The chief productive sand is at 600–800 feet. The Mississippi Lime lies at about 900 feet.

The wells come in at 10–50 barrels a day.

Stone Bluff (Wagoner County)

This small but prolific oilfield occupies a square mile in the southwest corner of Wagoner County.

The productive sand lies at about 1,200 feet.

The first well came in at 200 barrels a day in November, 1915. Considerable development ensued and a number of good wells were obtained, some of which gave an initial yield of 1,500 barrels a day. There were also gas wells with capacity 25 million cubic feet per day. The field was rather fully drilled in 1916 and has now declined. During 1919, the Haskell and Stone Bluff fields together were producing 2,000 barrels a day.

Coweta Oilfield (Wagoner County)

This small field lies near the west edge of Wagoner County around the town of Coweta.

The rocks at the surface belong to the lower part of the Pennsylvanian.

A number of productive sands are recorded, the chief ones being.

The Burgess Sand,	at 1,050 feet.
The Mounds Sand,	at 1,450 feet.

The development commenced in 1914, and some of the wells came in at 100-300 barrels a day. During 1918 some very good wells were obtained and the production was considerably increased; but it has since declined. In the latter part of 1919, there was an output of 400 barrels a day.

Dewey-Bartlesville Oilfield (Washington County)

This large field is spread over some 100 square miles in the middle portion of Washington County and an adjoining part of Osage County.

In the north of the field, the surface beds are about the horizon of the Dewey Limestone; and farther south they are about the horizon of the Hogshooter Limestone.

This field includes a number of pools occupying different geological structures.

The important sands are:—

Sand	*Thickness*	*Depth*
Peru	35	700
Skinner	26	1,050
Bartlesville	32	1,250
Burgess	34	1,340

The Bartlesville Sand, which has been the chief producer, generally lies at 1,250–1,500 feet. It is 350 feet beneath the Fort Scott Limestone.

The principal gas horizon is the Burgess Sand, which is 150 feet below the Bartlesville.

The Dewey, the Peru and the Squirrel Sand also yield oil in some parts of the field, and there was also some shallow production from the McEwin Sand at 525–650 feet.

The extensive development of this oilfield took place during 1904, 1905 and 1906; and in those years many wells at first produced 1,000 barrels a day, or more.

The average initial yield in 1906 was 73.2 barrels a day but in 1914 it was only 10.4. At the end of 1914 there were 4,816 producing oil wells.

There were also many gas wells yielding 5-15 million cubic feet a day with a pressure of about 500 pounds. Southeast of Dewey there was a group of gas wells which had capacities of 20-30 million cubic feet.

It is stated that the output of the Bartlesville field was,

at the beginning of	1907	38,000	barrels a day.
during	1915	16,700	barrels a day.
at the end of	1918	4,600	barrels a day.
during	1919	4,300	barrels a day.

Statistics for a part of this oilfield, having an area of 11,000 acres, show that 20 million barrels of oil have been obtained; which is an average yield of 1,800 barrels per acre.

Canary-Copan Oilfield (Washington County)

This oilfield is in the northeast part of Washington County, north of the Dewey-Bartlesville field.

The Copan Shales are at the surface in this district.

The productive sands are:

The Bartlesville oil sand	depth 1,175–1,450.
The Burgess gas sand	depth 1,450–1,700.

The Bartlesville Sand is about 50 feet thick. From the top part of it gas is obtained, and from the lower part, oil. Many of the early wells gave several hundred barrels a day and, there were many gas wells with capacity 30 million cubic feet and pressure 500 pounds.

The field was opened in 1907, the average initial production of the wells being 54.4 barrels.

The output of the Copan-Wann district in June, 1919 was about 500 barrels a day.

Wann Oilfield (Washington County)

This small oilfield is situated near the northeast corner of Washington County, east of the Copan field.

Oil is obtained from the Bartlesville Sand at 1,000 feet, and gas from the Burgess Sand at 12,000 feet.

Hogshooter Oilfield (Washington County)

This field is in the east central part of Washington County, extending for 14 miles along the east edge of the county. It lies southeast of the Dewey-Bartlesville field and is almost continuous with it.

The rocks at the surface belong to the middle portion of the Pennsylvanian.

The principal sands are:

Shallow Sand	500 feet.
Bixler Sand	710 feet.
Sand	880 feet.
Bartlesville Sand	1,080 feet.
Burgess Gas Sand	1,160 feet.

Some of the oil wells came in at 500 barrels a day, and the gas wells had capacity 5–15 million cubic feet a day.

The development of this pool began in 1907. The northwest part of the field yields principally oil, but the greater part of the area yields gas and is one of the chief gasfields in the State. At the end of 1914 about 2,500 wells had been drilled. In the year 1909 the average initial production per well was 50 barrels, but in 1914 the figure was 10.4.

During 1919, the Hogshooter district was yielding 1,600 barrels a day.

Vera Oilfield (Washington County)

This small oil and gasfield occupies some 6 square miles in the southeast corner of Washington County.

The development at Vera began in 1915, when 25 oil wells and 9 gas wells were brought in. There was increased activity in 1916. Some of the wells gave initial production of 300 barrels a day, but the average in 1915 was 60 barrels.

SECTION D

THE PENNSYLVANIAN IN SOUTH-EAST OKLAHOMA

In the southeast part of Oklahoma, south of the oilfields as we approach the Ouachita mountain uplift, the Pennsylvanian attains great thickness. The numerous limestones have died out and we have 15,000 feet or more of shales, coal measures, sandstones and conglomerates. Evidently much sediment entered the Pennsylvanian sea from the shores of the uplift mass.

The change of conditions is gradual as we go from northeast Oklahoma into southeast Oklahoma—but we may consider this district to commence about midway from north to south, or, in other words, it lies south and southeast of the Canadian River. It terminates southward at the Ouchita uplift mountain mass.

In structure also, this district differs from northern Oklahoma, for here the strata have been thrown into a series of comparatively sharp folds. (See Part IV and Part VII.)

The coal deposits are of considerable importance. In accordance with the greater folding and compression of the rocks, the coal is of higher quality and contains a higher percentage of fixed carbon.

Some valuable gasfields have been developed on the folds, but the gas is not accompanied by oil. These facts afford an interesting illustration of the law established by Dr. White.

The district was studied in detail by J. A. Taff,* who gives the succession in Pittsburg, Latimer and Le Flore Counties as follows:—

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* U. S. Geol. Surv., Twenty-first Annual Report, pp. 271–279.

14.	Seminole conglomerate	50	feet
13.	Holdenville shale	260	"
12.	Wewoka formation	700	"
11.	Wetumka shale	120	"
10.	Calvin sandstone	200	"
9.	Senora formation	500	"
8.	Stuart shale	90– 280	"
7.	Thurman sandstone	80– 250	"
6.	Boggy shale	2,000–3,000	"
5.	Savanna sandstone	1,200–1,500	"
4.	McAlester shale	2,000–2,500	"
3.	Hartshorne sandstone	100– 200	"
2.	Atoka formation	2,000–7,000	"
1.	Wapanucka limestone	100	"
	TOTAL—approximately	14,900	feet

GASFIELDS OF SOUTHEAST OKLAHOMA AND ARKANSAS PRODUCING FROM THE PENNSYLVANIAN

The following notes in small type, are gathered from various sources. The more recent items are from the oil journals.

Poteau Gasfield (Le Flore County)

This field is about 20 miles north of the Ouachita uplift-mass, near the Arkansas State-line.

It is situated on or near to the axis of the Poteau Anticline, which is a sharp fold extending in a northeast direction into Arkansas.

The rocks at the surface belong to the McAlester Shale, of the Pennsylvanian.

The depths of the wells are from 1,300 to 1,900 feet—generally about 1,500 feet, and the gas is found in a sand about 200 feet thick which appears to be the top of the Hartshorne Sandstone.

The drilling commenced in 1910; and in 1916 there were 15 or more wells.

The early wells showed a capacity of from ¼ to 18 million cubic feet and a pressure of 412 pounds.

The gas is supplied to the town of Poteau.

Quinton-Kinta Gasfield (Pittsburg County)

A small gasfield has been developed near Quinton at the east edge of the north half of Pittsburg County and in the adjoining part of Haskell County. The wells are located on the Kinta anticline.

The depth of the well is 900–1,600 feet, the capacity 5–20 million cubic feet, and the pressure 400–700 pounds. In 1916 there were but 8 producers.

Several Small Gasfields (various counties)

Several smaller gasfields, or occasional gas wells, are producing in Haskell County at Stigler and other places; in Pittsburg County at various localities; and in Latimer County.

In Coal County a considerable amount of gas is found on the Savanna Anticline and the Coalgate Anticline.

In Atoka County, also, some gas is found on the folds.

In Pontotoc County, farther northwest, there is the Ada gasfield, with gas sands at 900 and 1,200 feet, the wells having capacity 2 to 16 million cubic feet. The stratigraphy and structure in this county require further study, but presumably the Allen oilfield at the north border, with oil at 800 feet, lies north of the strongly folded area.

Massard Prairie Gasfield (Sebastian County)

This gasfield is at Massard Prairie 5 miles southeast of Fort Smith, Arkansas.

The surface is occupied by the Hartshorne Sandstone and the gas is found in a number of sands in the Atoka formation at depth 1,000–2,100 feet.

The wells had capacity up to 4 million cubic feet and pressure 280 pounds.

The gas was piped to Fort Smith and Van Buren, but the supply is now no longer equal to the demand. At the end of 1916 there were 83 wells in service, but the pressure had fallen to 21 pounds.

Kibler Gasfield (Crawford County)

This field which lies about 12 miles northeast of the older Fort Smith gasfield, was opened in 1915, and during the following year 24 producing wells were drilled.

It is stated (July, 1919) that there are now 50 producing wells, with a total potential yield of 130 million cubic feet a day.

The wells have depths 2,100–2,500 feet and capacity 3–25 million cubic feet per day. The pressure is 285 pounds.

The gas is piped to Fort Smith, Van Buren and Kibler.

SECTION E

THE PENNSYLVANIAN IN NORTH TEXAS

In north central Texas the output of the Pennsylvanian rocks occupies a large area, which is separated from the outcrops in Oklahoma by the Arbuckle uplift and by overlying Cretaceous rocks.

The Pennsylvanian and lowest member of the Permian of North Texas have a thickness of 5,000–7,000 feet.

Permian	Wichita-Albany, 1,000–1,500 ft.	This series, in Wichita County, consists of red, bluish and gray sandstone, red clay-shale and some blue shales. The dominant color is red; but in Young County and thence southwards it consists of blue-black clay-shales and massive limestones, and is known as the Albany formation. It yields the shallow oil at Electra (Wichita Co.) and at Petrolia (Clay Co.).
Pennsylvanian	Cisco 900 feet.	Blue clay-shales, sandstones, conglomerates, some thin limestones and important coals. Yields oil at Moran (Shackleford Co.), at Abilene (Taylor Co.) and the deep oil of the Petrolia and Electra-Burkburnett fields.
	Canyon, 600–800 ft.	Limestones, blue clay-shales, some sandstones and conglomerate, also some coal. Yields shallow oil at Brownwood (Brown Co.) and at Lohn (McCulloch Co.).
	Strawn, 1,700–4,000 ft.	Sandstones and blue clay-shales, some conglomerates, a few limestones and several coal seams. Yields oil at Strawn (Palo Pinto Co.), Millsap (Parker Co.) and Moran (Shackleford Co.).

These deposits lie unconformably on the Bend formation of the Mississippian, which has already been described. Passing northward towards the Arbuckle uplift-mass, the accumulation thickens—limestones die out whilst sandstones increase and assume a reddish color.

This pile of Pennsylvanian and Permian strata has a general inclination towards the west or northwest, at 30–90 feet per mile. Beneath it the Bend formation seems to be folded into an extensive, broad anticlinal arch.

It is said that this arch is not discernible in the Pennsylvanian. But the monoclinal attitude of the Pennsylvanian beds is interrupted by numerous minor folds, which have been impressed also on the Bend formation below.

Many geologists are working in this district, and a considerable number of these anticlines and domes have now been mapped.

The minor folds have a general N. W. trend, and are very slight, but it is considered that they are more strongly developed on the underlying Bend formation.

The Ranger "nose" once was mapped and rejected by several companies, on account of its apparent insignificance; but now a structure with a closure of 10 feet is regarded as a promising location.

The chief objective of the drillers during 1918 was the Bend Series of the Mississippian, which is being reached at 3,000–4,000 feet in Comanche, Eastland, Stevens and Coleman Counties, and is yielding prolific results (see description of Mississippian, Part VI, Chapter 4.)

But the Pennsylvanian and Permian also have been yielding a large amount of oil for a number of years, and are at present producing over three million barrels a month. The petroleum is distributed throughout the whole vertical column.

The Strawn Formation is productive in the small oilfields of Moran and Strawn. The latter field is now making a thousand barrels a day, and both have also a considerable amount of gas.

The Canyon Formation probably contains the important deeper sands of the Electra and Burkburnett fields of Wichita County, in which many of the wells come in at 1,000–2,000 barrels a day and provide nearly half of the north Texas output.

This formation is interesting also on account of the remarkable shallow production in the Brownwood field, which has been developed so rapidly during 1918. Here there are now several hundred wells, only 200–300 feet deep, which, together, have been producing 2,000–3,000 barrels a day.

The Cisco Formation gives shallow oil at Moran and some other small fields, but it is more important for its contribution to the Electra and Burkburnett output. Probably some of the rather deep sands of those fields belong to the lower part of the Cisco formation, though the deepest sands are more likely to be in the formation below.

The chief gasfield of north Texas—the Petrolia field (Clay County),—produces its gas, and a little oil, from a sand which probably belongs to this formation. Here, a few years ago, there were many wells with capacity 10–40 million cubic feet per day, at a depth of 1,500 to 1,750 feet; but as a producer of gas the field is now in its decline.

The Wichita-Albany Formation belongs to the Permian System. In Wichita County it consists principally of red rocks, similar to those of southern Oklahoma, but traced southwards the deposits become marine in character, and are generally known as the Albany formation.

The Petrolia oil and gasfield is situated on the red beds of the Wichita formation. For several years this field has been making upwards of a thousand barrels a day, from sands at 80–300 feet. The gas, however, comes from deeper sands in the Cisco and Canyon formations.

In the Electra field the shallow oil sands at 600–800 feet also are in the Wichita formation.

	Formation	*Oilfield*	*County*	*Depth*
Permian	Wichita-Albany	Petrolia	Clay	300
		Electra	Wichita	600–800
Pennsylvanian	Cisco	Petrolia	Clay	1,500–1,800
		Electra	Wichita	1,400–1,600
		Burkburnett	Wichita	1,600–1,800
		Moran	Shackleford	600–2,150
		Abilene	Taylor	2,100
	Canyon	Electra	Wichita	1,800–2,000
		Burkburnett	Wichita	1,700–1,900
		Abilene	Taylor	Deep
		Brownwood	Brown	100–350
		Lohn	McCulloch	Shallow
	Strawn	Strawn	Palo Pinto	800–1,000
		Moran	Shackleford	2,500
		Millsap	Parker	2,150
Mississippian	Bend	Caddo	Stevens	3,150
		Breckenridge	Stevens	3,200
		Ranger	Eastland	3,400
		Coleman	Coleman	3,400
		Santa Anna	Coleman	1,560
		Trickham	Coleman	1,050–1,200
		Gray	Coleman	2,400
		Desdemona	Comanche	2,700

OILFIELDS IN NORTH TEXAS PRODUCING FROM THE PENNSYLVANIAN

The following notes, in small type, relating to individual oilfields, are gathered from many sources. The more recent items are from the various oil journals.

Brownwood Oilfield (Brown County)

This interesting shallow field is the southernmost producing area of any importance in the Mid Continent Oil Region.

It is about 30 miles north of the Llano-Burnett uplift, and is situated on beds of Pennsylvanian age.

The oil is obtained from sands in the Canyon formation, at depths of 200 to 300 feet.

The field was opened up during 1917, and by the end of the year there were 200, or more, producing wells, yielding from 10 to 25 barrels a day.

During 1918 an output of about 2,000 barrels a day was maintained. The daily yield, in July, 1919, was 900 barrels; and the number of wells was 620.

Petrolia (Henrietta) Oil and Gas Field (Clay County)

This field, near the north border of Texas, lies about 45 miles south from the east end of the Wichita uplift-mass of older rocks.

The surface is occupied by the red rocks of the Wichita formation, of Permian age. The exposed beds are lenticular red shales, soft, cross-bedded sandstone, and some blue-gray shales.

The productive ground is situated on an irregular dome. (See Part VII, Chapter 19.)

Production is obtained from:

(1) Shallow oil sands, at about 300 feet, in the Wichita formation of the Permian.

(2) Deeper oil and gas sands, at 1,500–1,750 feet in the Cisco formation of the Pennsylvanian.

The district was first exploited as an oilfield in the shallow sands. The first shipments were made in 1904, in which year 75 oil wells were drilled. The output of oil averaged about 100,000 barrels a year up to the end of 1911.

the deeper sands were discovered, and the
mportant as the chief gasfield in Texas. The
a capacity of 10–40 million cubic feet per day,
0 pounds.
d to Dallas and Fort Worth in 1909.
15 some 50,000 million cubic feet of gas had
the earth in this field, and the pressure had
s.
the pressure had declined to only 175 pounds,
to be nearing exhaustion.
ount of oil, also, has been found in the deeper
ut increased to 550,585 barrels in 1914. Since
been a decline. The production for 1918 was
he output in the latter part of 1919 was 500
gether, up to the end of 1919 about four mil-
ve been obtained.
h quality. An analysis of oil from depth of
he Texas University Bull. No. 246, shows:—

grav.	.802
ate to 150° C.	35%

ting, in that it contains over 30 percent of
1% of Helium. (See Part IX, Chapter 6.)

Pinto County)
southwest corner of Palo Pinto County, is
e Ranger pool. It is situated on, and about,
re visible in the Pennsylvanian beds. (See

consist of clay-shales with beds of sandstone
d frequent limestone bands, 2–12 feet thick.
ds at first developed lay at depth 800–1,000
rmation; and the wells were only small pro-

aluable yield of gas is obtained—the total ca-
ells being estimated in 1916 at 50 million

Deep drilling is now in progress, but no important result is yet announced.

The field was opened in 1914, and at the end of 1918 there was a daily yield of 800 barrels. In July, 1919, the output was 250 barrels a day.

The production for 1918 was 221,093 barrels.

Moran Oilfield (Shackleford County)

This field lies 80 miles north of the Llano-Burnett uplift-mass, and about 20 miles west of the Ranger wells.

It is situated on the Pennsylvanian deposits, and produces at various depths between 600 and 2,150 feet, from sands supposed to belong to the Cisco formation, and also at 2,500 feet, from the Strawn formation.

The field was brought into production in 1913; and in 1914 there was an output of 68,000 barrels of oil.

In 1916 the production had increased to 165,000 barrels, but since that date there has been some decline; and for 1918 the total probably did not exceed 60,000 barrels. The output in August, 1919, was about 100 barrels a day. There is also a considerable production of gas which is now being utilized.

Breckenridge and New Caddo Field (Stevens County)

These fields are situated on the Pennsylvanian beds.

There is some valuable gas production at about 2,000-2,100 feet in the Strawn formation; but the oil is obtained in the Bend Series at 3,150–3,200 feet (see Chapter 4, Section E).

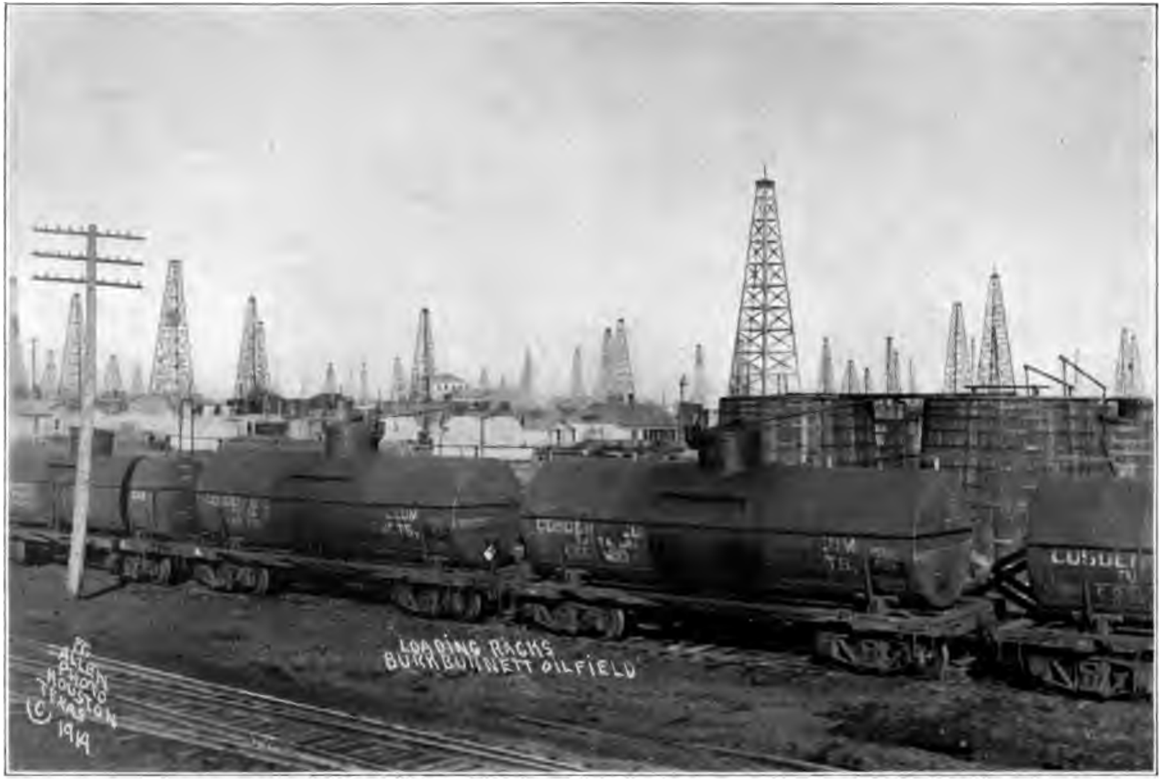
The Stevens County fields were opened in 1917. They are now being extensively developed, and during the latter half of 1919, were producing 41,000 barrels of oil per day.

Electra-Burkburnett Oilfield (Wichita County)

This field is close to the north border of Texas, about 45 miles south of the Wichita uplift-mass of older rocks.

The surface is occupied by the red beds of the Permian, here known as the Wichita formation.

Part of the output is from shallow sands in the Permian, but the principal production is from the Pennsylvanian.



View No. 7. The Burkburnett Oilfield.

(*Photograph lent by the Oil Trade Journal.*)

Many oilsands are encountered in this field—

Sands at 500 - 820 ft., probably in the Wichita formation.
Sands at 950 - 1,600 ft., probably in the Cisco formation.
Sands at 1,700 - 2,000 ft., possibly in the Canyon formation.

The Electra field was opened up in the year 1911, and the development was very rapid. The field has since been extended over a large area, reaching eastward to Burkburnett and beyond.

In the first year the production was mainly from the shallow sands, and the majority of the wells gave less than 100 barrels a day.

In 1913 and also in 1914 the output exceeded 8 million barrels; after which there was a decline.

In 1916, however, the exploitation of the deeper sands greatly increased the production, many of the wells having an initial yield of over 1,000 barrels a day.

With this revival of activity the field was further extended, and in 1917 the Burkburnett district became more important than that of Electra.

In 1918 very rich territory was discovered within the village of Burkburnett, many of the wells having an initial yield of 1,000–2,000 barrels a day, from the sands at about 1,700–1,900 feet. A large production was rapidly developed, and in a few months the village had become a town. In August, 1919, the Burkburnett pool was producing 110,000 barrels a day, and the Electra field 1,200 barrels a day. The total number of wells was about 5,500.

The output for 1919 is likely to be near 26 million barrels, and altogether up to the end of the year, the Electra-Burkburnett field will have yielded over 90 million barrels of oil.

Production,	1911	899,579	barrels
"	1912	4,227,104	"
"	1913	8,131,624	"
"	1914	8,227,968	"
"	1915	5,833,951	"
"	1916	7,837,386	"
"	1917	9,625,037	"
"	1818	11,649,408	"
"	1919	26,000,000	"

Analyses of the oil (5 samples) were published by the University of Texas. According to these, the properties are:

Color	Reddish brown.
Spec. grav.	.813–.845 (42.5–36.1 Be.)
Distillate up to 150° C.	20–28.5%.
Distillate 150°–300° C.	28–61%.
Depth of samples	870–1,910 feet.

Iowa Park Oilfield (Wichita County)

This small producing area lies about 6 miles south of the Electra-Burkburnett field.

It is situated on the Permian red rocks, and the oil is obtained from shallow sands.

The yield during 1918 was approximately 20,000 barrels. In 1919 the output was 300–500 barrels a day. The number of wells is about 100.

CHAPTER VI

THE RED BEDS OF THE PERMIAN SYSTEM

SECTION A

GENERAL CHARACTER OF THE RED DEPOSITS

The Red Permian Rocks at present are productive only in southern Oklahoma and north Texas, and these are the highest oil horizons exploited in the Mid Continent Fields.

Across Kansas and north Oklahoma, the outcrop of the Permian Red Beds occupies a wide strip of territory, west of the Pennsylvanian and the Lower or Marine Permian formation. Continuing further southward, the Red deposits gradually swell out in thickness until in southern Oklahoma and north Texas, the whole of the Permian System is represented by them. Proceeding further southward towards the center of Texas, the lowest member of the Permian System (Wichita Formation), gradually passes into a marine series known as the Albany Formation.

The Red Beds consist of red clay-shale and red sandstones with beds of gray sandstone, gray shale, gypsum, salt, and thin bands of dolomite. The thickness is 2,000–2,500 feet in Kansas; 2,500–3,500 in Oklahoma; and in north Texas it is stated to be 5,000–5,500 feet.

Organic remains are scarce, and as a rule there is a complete absence of hydrocarbons, which accords with the highly oxidized condition indicated by the general red color of the deposits.

In many places in Kansas and north Oklahoma, test wells have been drilled right through the red beds without any success.

These Permian deposits share in the monoclinal structure of the region, but owing to irregularity of character, cross-bedding and discontinuity of beds, it is difficult to make precise measurements. Probably the general dip to westward is about 20 to 60 feet per mile.

SECTION B

RED BEDS OF THE PERMIAN IN SOUTHERN OKLAHOMA

In the south part of Oklahoma the Permian is wholly represented by the red type of deposits. Evidently the ocean withdrew and gave place to continental conditions earlier in this part of the region.

In southern Oklahoma, the Permian Red Beds around the Wichita and Arbuckle uplift-masses, overlap the Pennsylvanian, and lie directly upon Lower Palæozoic and older rocks.

These two "uplift-masses"—the Wichita and the Arbuckle—which occur along an east-and-west line in southern Oklahoma, have anticlinal character and the Permian beds which now are exposed along their margins, at one time extended completely over their crests. The mountains appear to have been raised by at least three movements. The first was at the close of the Mississippian, and the second near the end of the Pennsylvanian. Each of these upward movements was followed by erosion and degradation of the uplifted mass, and the Permian deposits were formed largely of the materials removed from the mountains after the second uplift. Since the deposition of the Permian beds, there has been a slight continuation of the upfolding movement which has bent the Permian strata, covering the region, into a low anticlinal arch. Thus, on the north side of the Wichita Arbuckle axis, the Permian beds are dipping gently towards the north, and on the south side, they have a gentle southward dip.

In this part of Oklahoma and at the north border of Texas, there are some scattered oilfields and gasfields, situated on these Red Permian Beds. These fields obtain all or part of their oil from the Permian, wherein they differ entirely from the oilfields of the main productive areas of the Mid Continent Region. They include the important oilfield of Healdton which is one of the world's notable fields.

This production is particularly interesting in that the Permian Red Beds seem to be an unlikely source of oil; and it is generally thought that the oil must have migrated into them from adjacent or underlying Pennsylvanian or Lower Palæozoic rocks.

The oil is obtained almost wholly from those parts of the deposits which are in close contact with other formations. Thus, in the oilfields around the Wichita and Arbuckle uplifts, the oil-bearing sands generally are near the bottom of the red beds, not far from their contact with Pennsylvanian or older marine beds.

The fields are situated on gentle anticlines and domes.

The district is also interesting for the abundant showings of asphaltum in the outcrop of the red rocks.

The oil and gas fields producing from the Red Beds of the Permian System, taking them in order from west to east, and from north to south, are briefly noted below.

OILFIELDS IN SOUTHERN OKLAHOMA PRODUCING FROM THE PERMIAN RED BEDS

The following notes, in small type, relating to individual oilfields, are gathered from many sources. The more recent items are from the various oil journals.

Granite Oilfield (Greer County)

This small oilfield lies near to the west end of the Wichita uplift-mass of older rocks. The beds at the surface are the red sandstones and shales of the Permian. Granite has been encountered in several of the wells, at less than 1,000 feet.

The first wells were drilled in 1901, and others have been drilled in 1903 and 1913; but the results have been disappointing. A very small yield of heavy black oil has been obtained—and a few million cubic feet of gas.

Gotebo Oilfield (Kiowa County)

This oilfield is located some 10 miles north of the Wichita uplift-mass, on the Permian Red Beds.

The production is from sands at depth 350–600 feet, near the base of the Permian.

In 1910, there were 19 wells producing oil or gas—and up to the end of 1914, about 150 wells had been drilled. The yield of the wells varied from 2 to 20 barrels of oil per day, and some of them had a gas capacity of about half a million cubic feet.

Lawton Oil and Gas Field (Comanche County)

This field is situated 8 miles southeast of the Wichita Mountains, on the red measures of the Permian System.

Between the oilfield and the mountains, there are many seepages of heavy oil, and some of the sandstone-outcrops are asphaltic, and have been quarried.

The oil and gas are found in three sands, at depths of 200 feet, 400 feet, and 800 feet.

The structure is an irregular dome (which is further mentioned in Part VII).

The discovery well was drilled in 1910; and in 1916 there were some 50 or more producers, occupying an area of about 3 square miles. They yield from 10 to 40 barrels of oil, and the gas wells give about a million cubic feet of gas per day. The total output at the end of 1917 was 125 barrels a day.

Duncan Gasfield (Stevens County)

The Duncan or Hope field lies about midway between the Wichita and Arbuckle uplift-masses, a few miles north of the axis.

The surface rocks are the Red Permian Beds, consisting of red and blue-gray shales, with buff or red sandstone, some calcareous sandstones, and shale-conglomerate. The drilling proved that beds of this character continue down to about 1,900 feet, at which depth a 20-foot limestone was found, which is supposed to belong to the Pennsylvanian.

The gas sand is about 900 feet above the supposed base of the Permian, and lies at a depth of 800–900 feet.

The field is situated on a well-marked anticline; with a dip on either side, of about 350 feet in one mile (see Part VII).

The field was discovered in 1907, and has been utilized to supply gas to the town of Duncan about 10 miles distant. Only a few wells have been drilled—their capacity varying from 3 million to 18 million cubic feet a day.

Loco Gasfield (Stevens County)

This gasfield is about 20 miles west from the Arbuckle uplift-mass. The rocks exposed are the sandstones, shales and conglomerate of the Red Permian Beds.

Some of the outcropping sandstones are asphaltic, and have been exploited to a small extent.

The principal gas sand lies within 250 feet of the base of the Permian, at a depth from the surface of 650–750 feet.

Beneath the Permian, there are limestones and dark shales considered as Pennsylvanian. Some showings of oil have been found in them.

The field is situated on an anticlinal fold (further mentioned in Part VII).

The first wells were drilled in 1913. A number of good producers have been obtained during the past two or three years. Their capacity ranges from 6 to 20 million cubic feet of gas per day.

Walters Oilfield (Cotton County)

In the northeast part of Cotton County, about 20 miles south of the Lawton field, a new oilfield is being developed.

The rocks at the surface belong to the Red Beds of the Permian, but as the production is at 2,100–2,500 feet, the oil and gas probably are in the Pennsylvanian.

The discovery was made in 1918, and there is now, at the close of 1919, a large production of gas, and a daily output of 6,000 barrels of oil.

The gas wells are of fairly large capacity, and a number of the oil wells have initial yields of several hundred barrels a day. Recently a well was brought in at 2,000 barrels a day.

Healdton Oilfield (Carter County)

The Healdton field lies southwest of the Arbuckle Mountains, the development extending to within eight miles of the outcrops of the older rocks.

The surface, which is of a rolling character with elevations 850 to 1,000 feet, is occupied by the Permian red rocks. The exposures show alternating beds of red and grey clay-shale, brown, white and red sandstone, and thin beds of conglomerate. They appear to be of estuarine or fluviatile deposition. Some plant remains and bones of animal are found.

The oil and gas occur in many seams, but there is a group of three or more principal sands with a thickness of 250 feet, the top of which is 600–950 feet below the surface. There is a large gas production of gas and some oil from the first of the three sands, and much oil and some gas from the other two sands.

Deep borings find, under the red beds, a series of alternating thick limestones and dark shales, which probably are of Pennsylvanian age.

The structure is an irregular dome—(described in Part VII).

The field was discovered in 1913. Some of the wells came in at 5,000 barrels a day, and gas wells with a daily capacity of 40 million cubic feet. The maximum output was in 1917, when some 22½ million barrels of oil were produced. Since that date, there has been a decline and the 1918 figure was under 17 million barrels. There were 2,070 producing wells at the end of 1919. In the latter part of 1919 the daily output was 37,000. Up to the end of 1919, about 126 million barrels of oil will have been produced from an area of 13 square miles.

The oil is darker and heavier than that of the oilfields of northeast Oklahoma, which produce from the Pennsylvanian. The specific gravity varies from .8105 to .8383 (42.7–27 Beaume).

Hewitt Oilfield (Carter County)

This new oil-pool lies 3 or 4 miles east of the southeast corner of the Healdon field, of which it may be considered an extension.

The oil is found in sands at depth of 1,650–2,150 feet.

The best well yet drilled came in recently at 1,000 barrels a day. The daily output of the field in December was reported as 4,000 barrels.

Wheeler Oilfield (Carter County)

This oilfield lies 15 miles southwest from the west end of the Arbuckle mountain mass.

The surface is fairly flat, and has an elevation of about 900 feet above sea. It is occupied by the Red Measures of the Permian System, which lie almost horizontal. The formation consists of alternating sandstones and shales, with occasional lentils of limestone. There is here one of the largest deposits of asphaltum in the United States.

The productive sands lie at a depth of 850–1,000 feet, and are just above the base of the Permian. The Red Beds are underlain by a great thickness of dark shales and limestones of the Pennsylvanian.

Development commenced in 1904 and the productive area is about 4 square miles. The number of wells which have produced oil or gas is about 100. They yield 3–14 million cubic feet of gas from the principal gas sand, and a few barrels of oil from an oil sand which is almost immediately beneath it. The oil is heavy and asphaltic, with specific gravity .915–.933 (20–23 Beaume). The output at the end of 1917 was about 600 barrels a day.

Fox Oil and Gas Field (Carter County)

This field lies about 8 miles west of the Arbuckle Mountains and 10 miles north of Healdton. It is situated on the Red Permian Beds.

The productive sands lie at depths 1,450–2,350 feet.

The gas wells are of large capacity, ranging from 15 to 60 million cubic feet a day.

There are also a number of oilwells, some of which had initial yield of several hundred barrels a day.

This prolific gasfield was opened up in 1917, when many large gas wells were drilled. Some good oilwells also have been completed during the past two years.

Madill Oilfield (Marshall County)

This very small field lies some 20 miles south of the Arbuckle mass.

The wells are situated on Cretaceous rocks, but the oilsands are associated with red beds which have been considered, by some geologists, to belong to the underlying Permian. The depth of the wells is 420 feet.

The discovery was made in 1906, and in 1909 there were but 5 small producers. A few others have since been drilled, but little success has been achieved, and only a very small amount of oil has been shipped away.

The oil is rich in paraffin. Some of it has a specific gravity of .789 (47.5 Beaume) which is the lightest in the Mid Continent Fields.

SECTION C

RED BEDS OF THE PERMIAN IN NORTH TEXAS

In the north part of Texas the Permian has a thickness of 5,000–6,000 feet.

It has been subdivided into three main groups,

Double Mountain Formation Thickness 2,000 feet.
Sandstones, sandy shales, red and bluish clays, limestone and dolomite bands, and thick beds of gypsum and rock salt.

Clear Fork Formation Thickness 1,900 feet.
Red and blue clays, sandy shales, limestone and dolmite bands, white and red sandstones, gypsum and clay-ball conglomerate.

Wichita-Albany Formation Thickness 1,000–1,500 feet.
The Wichita consists of red and gray sandstones, red clays, some blue shales and clay-ball conglomerate.

The Albany consists of dark blue and gray marine shales, and hard compact limestone.

At the north border of Texas the whole of the Permian is of continental type, but to southward the lowest member,—the Wichita formation,—gradually passes into a marine series known as the Albany formation.

In the oilfield districts it is only this lowest member of the Permian that we are concerned with.

The oilfields of Electra, Burkburnett and Petrolia, in Wichita and Clay Counties, stand on the Wichita formation, which is here typically developed as a "Red Permian" formation.

But in Young County, and thence southwards we find, instead, the Albany formation, dark marine shales and massive limestones.

Oil is obtained in important quantity from the Wichita formation, in the fields of Electra, Burkburnett, Petrolia, and a few smaller fields in the same district.

It is to be observed, however, that by far the greater part of the production of these oilfields is from the underlying Pennsylvanian deposits.

Electra-Burkburnett Oilfield (Wichita County)

This field is at the north border of Texas, about 45 miles south of the Wichita uplift-mass of older rocks.

The surface is occupied by the red beds of the Permian, here known as the Wichita formation.

Only a small part of the output is from shallow sands, which are supposed to be in the Permian Red depositis, the principal yield being from the Pennsylvanian.

Many oil sands are encountered in this field.

Sands at 500 – 820 ft.—Probably in the Wichita formation (Permian).
Sands at 950 – 1,600 ft.—Proablably in the Cisco formation (Pennsylvanian).
Sands at 1,700 – 2,000 ft.—Possibly in the Canyon formation (Pennysylvanian).

The Electra field was opened up in the year 1911, and the development was very rapid.

The field has since been extended over a large area, reaching eastward to Burkburnett and beyond.

In the first year the drilling was shallow, and the oil came mainly from the sands of supposed Permian age. With the extension of the field, there has been continual shallow production—but these wells are only moderate producers.

Deeper drilling, especially in 1916 and since, caused a greatly increased production, many wells coming in at 1,000–2,000 barrels a day in the sands in the Pennsylvanian at 1,700–1,900 feet. (See Chapter 5, Section E.)

During 1918 there was great activity due to the opening of some very rich territory in the village of Burkburnett, and the output for 1919 will be near 26 million barrels.

The total amount of oil obtained from this field up to the end of 1919 will be about 90 million barrels—but only a small fraction of this came from the Permian sands.

Iowa Park Oilfield (Wichita County)

This is a small producing area, some 6 miles south of the Electra-Burkburnett field.

It is situated on the red Permian beds, and the oil is found in shallow sands. The wells are only small producers.

The output for 1918 was 20,000 barrels. In July, 1919, there was a yield of 300 barrels a day.

At Fowlkes and Eads, also, there is some production.

Petrolia Oil and Gas Field (Clay County)

This field is near the north border of Texas, about 50 miles south of the east end of the Wichita uplift rocks.

It is situated on an irregular dome, on the Permian red rocks, known here as the Wichita formation.

The production is obtained from:—

(1) Shallow oil sands, at about 300 feet in the Wichita formation of the Permian.

(2) Deeper gas and oil sands, at 1,500-1,750 feet in the Cisco formation of the Pennsylvanian.

The district was developed first as an oilfield, in the shallow sands.

The wells were small producers, but some few of them gave 100 barrels a day.

From 1904 to 1911 the annual output averaged about 100,000 barrels.

The deeper sands were discovered in 1907, and these have provided the most important gas supply in Texas. The early wells had an initial capacity of 10–40 million cubic feet a day, and a pressure of 740 pounds.

This gas was piped to Dallas and Forth Worth in 1909, but the field now seems to be nearing exhaustion. (See Part IX, Chapter 4.)

The deep sands gave also a considerable quantity of oil, and the production of the field increased until in 1914 it reached a maximum of over half a million barrels.

The output in 1919 was about 500 barrels a day, and the total amount of oil which has been obtained from the field is now about 3¼ million barrels.

Several analyses of the oil have been published by the Texas University (Bull. No. 246). The figures for two samples of the oil from the Permian rocks are given below:

	Depth, 350 ft.	Depth, 260 ft.
Color	Reddish brown	Reddish brown.
Sec. Grav.	.845	.861
Degrees Beaume.	39.5	32.8
Distillate to 150° C . . .	19.0	18.0

PART VII

THE OIL ACCUMULATIONS AND THEIR RELATION TO GEOLOGICAL STRUCTURE

CHAPTER I

OIL POOLS AND LOCAL STRUCTURE

SECTION A

SURFACE INDICATIONS

The manifestations at the surface, familiar in so many great oilfields, are not plentiful in the Mid Continent Region; thus, generally, we do not find extensive spreads of asphaltum, pitch-cones or mud-volcanoes; and seepages of oil or gas are rather scarce.

A few seepages occur along the outcrop of the Cherokee Series in eastern Kansas and northeast Oklahoma, and some of the exposed sands are slightly bituminous, containing small quantities of hydrocarbons, which can be extracted by solvents.

Some more extensive surface-showings are seen in the south part of Oklahoma, among the oilfields which are producing from the Permian. Here, at the outcrop of some of the red rocks, there are tarry seepages and an occasional mud volcano, and there are tar-sandstones of some commercial importance.

In north Texas, the Marble Falls Limestone of the Bend Series, which is such a rich, productive horizon, gives rise to tarry seepages at the outcrops, north of the Llano-Burnett uplift-mass.

The general scarcity of surface indications doubtless is due to the undisturbed attitude of the rocks which carry the oil. To this cause, also, may be due the long preservation of such an immense store. But, although so little oil is seen at the surface, large quantities were found at only a few hundred feet depth, in many of the earlier fields at the east side of the region.

SECTION B

OIL SANDS

The rock which actually contains the oil is generally a sandstone bed—sometimes coarse sandstone, sometimes fine. In some instances, beds only 10 feet thick have yielded abundantly, but in the richer fields the sand is usually from 35 to 100 feet thick.

These almost horizontal sheets of sandstone generally are more or less lenticular, though some of them are of wide extent and cover 100 square miles, or more. More than 95% of the oil of the Mid Continent fields has been obtained from ordinary sands.

Occasionally, however, the oil rock is a sandy limestone, perhaps with partings of shale, or a sandy band in a limestone. Such, for instance, are the Wheeler Sand, in the Cushing field, which is really the Oswego limestone or Fort Scott limestone; and the Black Lime in the new field of Ranger in north Texas, which is in the Marble Falls Limestone of Mississippian age.

Also, small quantities of oil have been yielded from rocks recorded by the drillers as shale, and some useful supplies of gas have been found in such beds, though the life of the wells is short.

SECTION C

OIL POOLS AND THEIR CAUSES

In general, the sandstones or other porous beds are occupied by water, and it is only in specially favored spots that the water has given place to oil or gas. These bodies of oil and gas, which here and there occupy the sandstone, are spoken of as "pools"—by which term they are fairly well described. Some of the pools are quite isolated and are clearly bounded, but many of them are connected together by strips of less productive land. Altogether, there are at least 200 well-known oil pools.

The belt of country in which the pools occur is 500 miles long and, in parts, 100 miles wide, with a total area of some 20,000 square miles. In some considerable portions of it, the pools are so numerous and extensive that the interspaces of barren country amount to less area than the productive ground.

The separate pools vary in size from 50 square miles, or more, down to one square mile, or less. The total area of all the fields together is about 2,000 square miles.

In some places, where there was a scramble to get the oil, the wells were placed much too close together, but the regular practice is to allow from 8 to 10 acres per well.

The largest fields, such as Bartlesville, Glen, Cushing, Healdton, Eldorado, etc., contain several thousand wells, and altogether about 123,000 holes have been drilled.

It is hardly necessary to state that there is no relation whatever between the oil bodies and the ocean level. In many of the fields there are oil pools several hundred feet above sea-level in the upper sands, and below sea-level in the lower sands—in some cases as much as 2,000–3,000 feet below.

Until recent years, little had been done towards finding satisfactory explanations for these "pools" of oil and gas, and the discoveries of oil were made by trial rather than by geological study. In the past few years, however, a great deal of geological surveying has been done, and a number of the newer pools have been thus discovered.

By detailed instrumental work it is found that the Prairie Plains monocline is by no means smooth, but abounds in minor folds and wrinkles. These minor anticlines, domes and terraces are of such slight degree that they can be mapped out only by fine instrument survey. A large number of these structures have now been studied and expressed on maps by structure contours.

Much of this work has been done in unexploited territory, and valuable results have followed—for instance, in the oilfields of Augusta and Eldorado, in Kansas; and the new fields in Garfield and Noble Counties, in Oklahoma.

Many of the older oilfields also have been examined, and in most cases it is found that the pools are situated on structures.

In some fields, however, where the structure contours have been mapped, no anticline or terrace has been found, and the reason for the oil pools is not apparent.

Probably such pools are due to the lenticular shape of the sandstones, for such a condition might provide a more effective trap for oil and gas than would an extremely gentle anticline. For example, a horizontal sandstone lens, 5 miles long and 5 miles wide, with a thickness of 60 feet in the middle and 10 feet at the margin, might imprison a very large bubble of oil or gas.

Again, variations in porosity could be equally effective. Thus, if a sheet of sandstone, traced eastward, passes into a fine-grained rock, with its pores sealed by lime, the more porous part of the bed, lower down the dip, to westward, would be an ideal oil trap, in which a great bubble of oil and gas might be held.

Faults, also, are a likely cause, and the actual facts at depth may be indeterminable at the surface. It may frequently happen that a sheet of sandstone is broken by a strike fault and that the broken edge of the main part of the sheet is sealed by being brought in contact with a bed of clay-shale. An effective reservoir is thus formed.

Besides the above, there doubtless are other factors, not yet appreciated or known, and in strata so nearly horizontal, these minor factors have much more scope than in fields where the dips are steep and the force of gravitation holds unhampered sway.

In the majority of the older fields the circumstances remain unknown because the fields were developed and drilled up, before these methods of investigation came into general use.

But, among such fields as have been studied, it is now thoroughly established that, as a general rule, the oil pools are located on structures, and the hydrostatic principle applies. The gas and oil are imprisoned over water, and their relative positions are approximately in accordance with the laws of gravity.

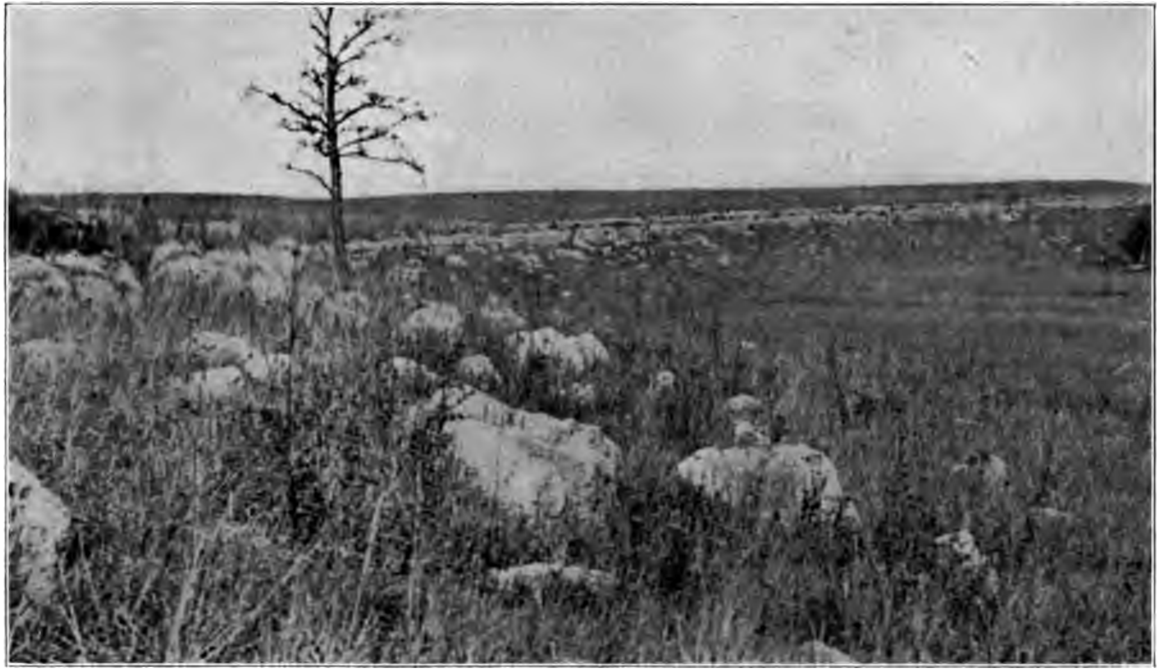
The situation of a gas pool or oil pool resembles that of a large air bubble, which has been trapped at some bend or concavity in the roof of a drain.

Apparently the oil and gas which were generated in the great mass of sediment which now constitutes the Prairie Plains Monocline, have gradually traveled eastward up the dip, along the porous beds, impelled by the resultant of gravitational forces; but, here and there, traps or obstacles to the movement have been encountered, and at these places accumulations or pools have gathered. Anticlines, domes and terraces are among the most obvious of the traps.

SECTION D

STRUCTURE SURVEY

In investigation of geological structure in the Mid Continent Fields, the manner of the survey is as follows: Some conspicuous bed, usually a limestone, whose outcrop is prominent throughout the district, is selected. Since the strata are almost horizontal, such a bed often causes plateaus with elaborate edges, winding about over a wide area, and with frequent outliers. As a rule, it is the top of the limestone which is mapped, but sometimes the base, or some special seam, is used. The outcrop is mapped accurately on a scale of 3, 4 or 6 inches to the mile, some hundred square miles, or more, being considered. The work is generally done on the plane table, using a telescopic alidade with stadia. The survey is carried on along the outcrop, making an accurate determination at selected positions, 100 to 500 feet apart. These must be chosen with much care to avoid places where there is any slipping or erosion. At each of the points where the instrument is set up, the altitude (relative to sea-level) is measured and marked on the map. A



View No. 8. Outcrop of the Fort Riley Limestone.

(*Photograph lent by Dr. R. C. Moore.*)

Wye or Dumpey level is used to control this work, if the levels have to be carried long distances from bench marks.

In those parts of the area from which the chosen limestone has been denuded, some other prominent bed must be employed—its depth beneath the first bed being ascertained.

The above process is much more easily described than carried out. Often there are large gaps in the evidence, and uncertainties due to slipping and erosion. The work is laborious and requires much time.

At length a map is obtained having the altitude of the limestone marked on it for a large number of points distributed all over the area.

Contour lines (at 5, 10 or 20 foot intervals) are then drawn, joining up the points of equal elevation. These structural contours display at a glance the shape of the surface of the limestone bed; or rather the shape which it would have if it were completely restored. Any anticlines, domes or terraces are plainly and precisely revealed. Such a map is of great value as a guide to the oil-bearing areas and also for deciding questions connected with depth of drilling, water troubles, etc.

Many maps of the above sort have been made by geologists employed by the numerous oil companies. These, however, are not available for publication. But many, also, have been prepared and published by the Government and State Geological Surveys.

SECTION E

STRUCTURE MAPS

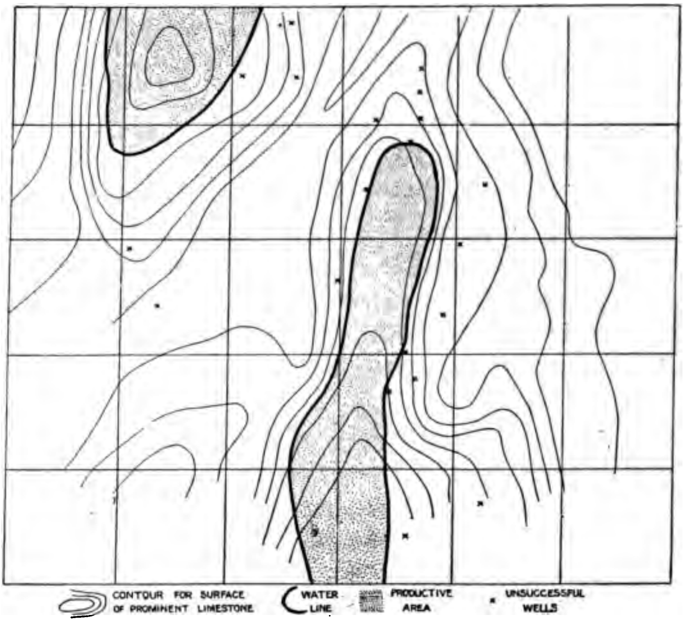
The type of structure map produced by the above method is represented in Fig. 13. The squares on the map are square miles, the fine lines are the structure contours for a certain prominent bed of limestone, and the numbers are the altitude, above sea-level, of the top of this limestone.

Two anticlines are clearly shown.

The thick line is the boundary of the productive territory, and is commonly known as the water-line. Inside this line almost every hole is an oil well, the largest producers lying along the crest and the smaller wells generally being those nearest to the margin. If there is much gas in the sand there will be large gas wells along the crest of the arch, but if there is little gas the best oil wells will occupy this position.

FIG. 13.

STRUCTURE MAP TYPICAL OF A MID CONTINENT OILFIELD



Scale, 3/5 inch = 1 mile.
Contour Interval, 10 feet.

The water-line is sharply defined. Outside of it, every well finds the sand full of water with, perhaps, traces of oil as we approach the line. The crosses represent some of these unfortunate wells.

As development proceeds and the field is drained of its gas and oil, the water-line gradually closes in.

In fields where the sand is thick and the dip is low, there is a wide outer rim to the productive area, in which the sand contains both oil and water. For example, if the sand is, say, 50 feet thick and the dip of the rocks is, say, 100 feet per mile, the width of this belt, theoretically, would be about half a mile.

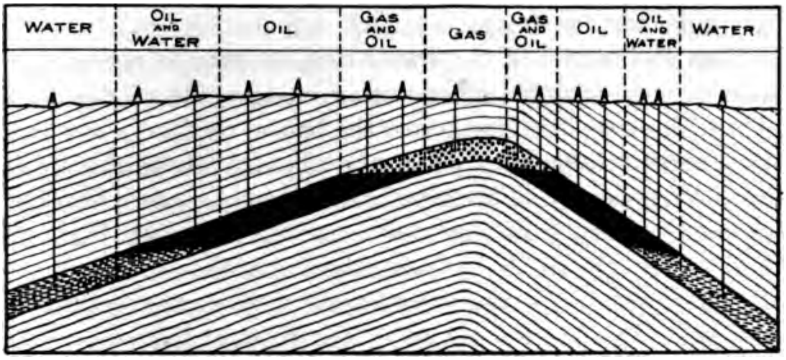


FIG. 14.

Diagram showing what fluids may be encountered by the wells according to their situation on the fold.

Within this belt a fairly good yield of oil may be obtained, for a time, by wells which drill into only the top part of the sand—taking care not to go down to the water-level.

But, as the development of the field proceeds, and the oil is withdrawn, the water rises and the water-line closes in. Thus, this belt is the first part of the field to suffer complete flooding of the oil sand.

SECTION F

INCLINATION OF THE WATER SURFACE

It is an interesting fact that the water-line is not parallel to the contours, but cuts them; that is to say, the water does not extend up the sandstone to the same level everywhere: or, in other words, the water surface is not horizontal.

In the illustration it is seen that the water stands 30 feet higher towards the northern end of the anticline than it does 3½ miles farther south.

This inclination of the water surface often is perceptible also even in a single cross-section on one side of the field. Thus, three wells in line across the belt of territory, in which the sand contains both water and oil, may strike the water at different levels. The slope of the water surface is directed outwards away from the center of the field (see Figs. 14 and 19), but its dip is less than the dip of the sandstone.

The cause of the unlevel attitude of the water surface is not yet fully known. By some it is thought that the water surface really is level before the wells are drilled, and that the inclination is a temporary condition, resulting from the withdrawal of oil and gas.

If the sand were a perfect conductor of the fluids, these inequalities of level could not be maintained, but, owing to the imperfection of the channels of circulation in the sand, considerable time might be required before the water would establish a new horizontal surface at its new level. But this is a matter which is not easily settled, because, for want of evidence, the position of the water-line cannot be drawn before the drilling of the wells.

We shall now briefly notice those structures which have been worked out, and have been made available for public use.

CHAPTER II

STRUCTURE OF THE AUGUSTA AND ELDORADO FIELDS

The structure of the Augusta and Eldorado fields of Butler County, Kansas, was worked out in detail by the geologists of certain oil companies (E. Carpenter and others).

A simplified edition of the structure map has been published in several books, and is shown in the accompanying figure. (Fig. 15.)

The structure was determined by measurement on the outcrops of certain limestone bands, which form prominent escarpments around these fields. The contours show the elevation of one of these limestones relative to sea-level. (In reading this map it is to be noted that only a few of the contours are given, and there are different intervals between them, ranging from 40 to 60 feet.)

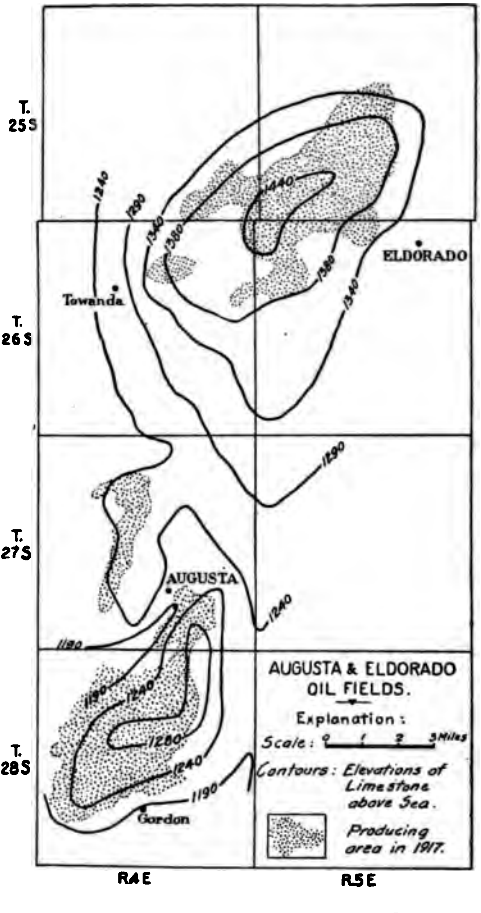
The producing area is now much larger than shown on this map, especially in the Eldorado district and around Towanda. (At the time this map was made, part of the most valuable territory was being held in reserve.)

The structure consists of a group of irregular domes or anticlines, lying along a N. N. E. line. The oil pools conform closely to these anticlines.

The three principal fields are shown on this map—one between Eldorado and Towanda; one northwest of Augusta; and one between Augusta and Gordon.

Two or three miles to northwest, to eastward, and to the south respectively, are the smaller fields of Potwin, Beaumont, and Douglas-Gordon.

FIG. 15.



The **Augusta-Gordon dome** is elongated and narrow. It has a closure of about 50 feet, and there is a dip of about 80 feet to the mile on the west side. The productive ground, 6 miles long and 1–4 miles wide, is in accord with the structure, and is mainly within the 1,240 ft. closed structure contour. Many of the most prolific wells are on the crest of the dome encircled by the 1,280 ft. closed structure line. The original gasfield was on this dome.

The Augusta anticline is long and narrow, with a dip of 40–60 feet per mile on either side, and with its axis pitching southward at 10 feet per mile. The productive area is a strip of land along the crest, about 4 miles in length and one-half a mile wide. It is very sharply defined, and the water-line can be drawn around it with precision.

The Eldorado-Towanda dome is large, wide, and more circular in form. There is a closure of about 100 feet; and the greater part of the area of closure is productive. The dip on the sides of this structure is 40–60 feet per mile.

A fine structure map of this dome, by L. Walker (for Fohs and Gardner), was recently published in the "Oil and Gas Journal." From it the accompanying sketch map (Fig. 16) was prepared.

The map was made previous to the development of this territory, which has proved so rich.

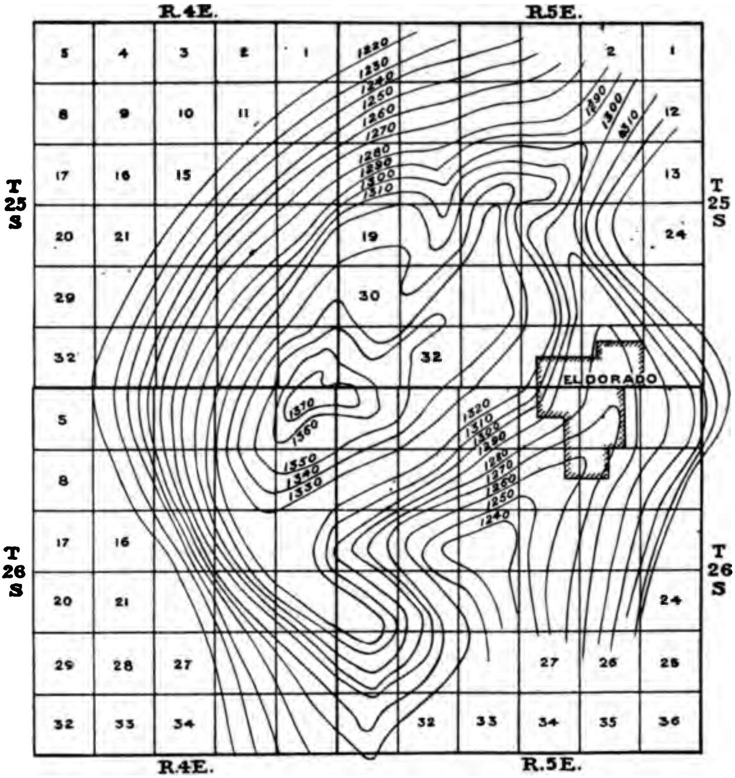
The principal producing sands in the Augusta-Eldorado field are:

Eldorado Shallow Oil Sand,	650 ft.	—Moderate production at Eldorado. Some flowing wells.
Augusta Gas Sand,	1,450 "	—The gas sand of the original gas field.
Upper Oil Sand,	1,750 "	—Moderate production.
Varner Sand,	2,450 "	—Great production.

This district was exploited first as a gasfield in 1913–1914. The wells were about 1,500 feet deep, and were situated on the crest of the Augusta-Gordon anticline. The Varner oil sand was discovered late in 1914.

The line of anticlinal folding was examined by E. Haworth in 1914. Subsequently the structure was worked out in detail by the geologists of certain oil companies, which were thus enabled to select the greater part of the territory which has since proved so rich. The principal development was in 1916, 1917 and 1918.

Fig. 16.



STRUCTURE MAP OF THE ELDORADO DOME.

Contour Interval, 10 feet.

(From map by L. Walker, for Fohs & Gardner. Published in the Oil & Gas Journal.)

These fields have provided the greatest oil wells of the

Mid Continent region. Many of them flowed at the rate of 10,000 barrels a day, and some of them exceeded 20,000.

The output reached a maximum of 115,850 barrels a day, for the month of April, 1918, and is now declining. The daily production for August, 1919, was 60,000 barrels.

In the five years, 1915–1919, the Eldorado and Augusta pools have yielded nearly 100 million barrels of oil from an area of about 35 square miles.

(For further particulars, see Part VI, Chap. 5, Section B.)

CHAPTER III

STRUCTURE OF THE CUSHING FIELD

General Account of the Structure

The structure of the Cushing field is illustrated in the structure contour map (Fig. 17), (prepared from plans accompanying Bulletin No. 18 of the Oklahoma State Geological Survey, by Frank Buttram).

The contours are for 20 foot intervals, and represent the Pawhuska limestone. On this map (west third of it) parts of two elongated domes are seen along an anticlinal axis. The northern one is known as the Dropright Dome, and the other one as the Drumright Dome. Continuing southward, beyond this map, are two others, the Mount Pleasant Dome and the Shamrock Dome.

The dip on the flank of these anticlines is unusually high. On the western side of the Dropright Dome it is as much as 170 feet per mile (2°). Continuing farther westward, it gradually decreases and the slope merges into the normal monoclinal.

The rich territory occupies the summits of the domes, and extends down the western slope for two miles, or more.

To eastward (west of center of map) there is a group of synclinal basins, intervening between the anticlinal and the regular monoclinal slope (eastern third of map).

Possibly this synclinal, occupied by water, prevented further movement of oil and gas towards the east, and so has played a prominent part in affecting the accumulation of the hydrocarbons on these anticlines.

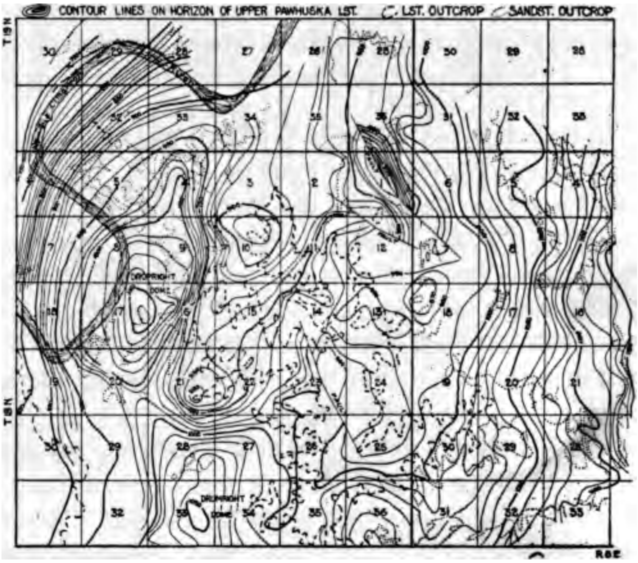


FIG. 17.

STRUCTURE MAP. NORTH PART OF CUSHING OILFIELD.

Contour Interval, 10 feet.

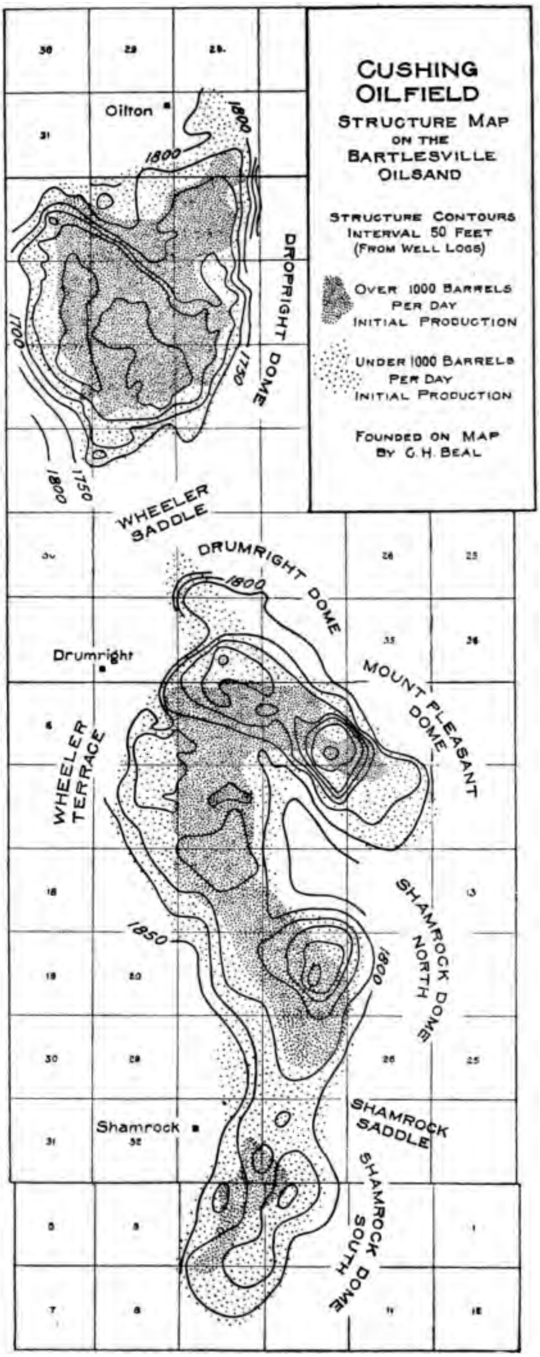
(*After F. Buttram, Oklahoma Geol. Surv.*)

On drilling down under these arches of Pawhuska limestone (for stratigraphy see Part VI), successive oil and gas pools are found in the sands, the important ones being in the:

Layton Sand,	Depth	1,530	feet.
Wheeler Sand,	"	2,330	"
Bartlesville Sand,	"	2,750	"

In the two upper sands there are powerful gas wells on the crests of the anticlines, giving as much as 30 to 40 million cubic feet a day. A little distance down the slope the

FIG. 18.


CUSHING OILFIELD
STRUCTURE MAP ON THE BARTLESVILLE OILSAND
STRUCTURE CONTOURS INTERVAL 50 FEET (FROM WELL LOGS)
OVER 1000 BARRELS PER DAY INITIAL PRODUCTION
UNDER 1000 BARRELS PER DAY INITIAL PRODUCTION
FOUNDED ON MAP BY C. H. BEAL
30
29
28.
31
Oilton
1800
1800
1800
1700
1750
1750
1800
DROPRIGHT DOME
WHEELER SADDLE
DRUMRIGHT DOME
1800
26
25
35
36
Drumright
MOUNT PLEASANT DOME
6
WHEELER TERRACE
18
13
1850
19
20
1800
SHAMROCK NORTH DOME
30
29
26
25
SHAMROCK SADDLE
Shamrock
31
32
SHAMROCK SOUTH DOME
6
5
1
7
8
11
12

best oil wells in these two sands were obtained. Continuing farther down the dip, the wells are less and less productive, until at length the water-line is reached. In the Wheeler Sand the oil extends somewhat farther down the slope than in the Layton Sand.

In the Bartlesville Sand there is less gas, and the heaviest yield of oil is obtained right on the anticlinal crest.

More recently the Cushing field has been studied in much detail by C. H. Beall,* of the United States Geological Survey. (See Fig. 18.) The results are shown on a beautiful series of maps accompanying Bulletin 658.

There are four independent structure maps of the whole field. One shows the form of the top of the Pawhuska limestone, which is exposed at the surface, and the others are for each of the three chief oil sands, as determined from the well records.

The main structural feature is the Cushing Anticline, a broad fold having a north-south direction. This main anticline is one of the largest in the Mid Continent Fields. Along its axis there are domes, and along the sides there are subsidiary folds and wrinkles. In order from north to south there are: the Dropright Dome, the Drumright Dome, the Mount Pleasant Dome and the Shamrock Dome; and to the west of these two latter domes there is the Wheeler Terrace.

There are considerable variations in the four maps, for the shapes of the structures are different at different depths. On each sand there are details which are not perceptible on the others. However, in all of the four maps the same main features are found, and the structure map of the Pawhuska Limestone, which crops out at the surface, is a satisfactory guide to the general form of the structure of all the sands beneath.

In each sand the oil and gas pools conform fairly well to the domes, and it is stated that if this district had been mapped earlier by this modern method the geologist probably would have selected almost the whole of the present oilfield (with the exception of the Wheeler Terrace) as territory likely to contain oil.

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* The information which follows is abstracted from Bulletin 658.

Steeper Folding at Greater Depth

One of the noteworthy facts brought out by Mr. Beall's work, is that the beds, deep underground, are more folded than those near the surface. The cause is obscure.

In the following table it is shown that the steeper folding underground is very pronounced:—

DROPRIGHT DOME

	Elevation of crest	AMOUNT OF DIP		
		2½ miles northeast of crest along anticline	*1½ miles west of crest*	*¾ mile east of crest*
Surface beds.........	+1,050	100	150	125
Layton sand.........	— 400	225	175	a 250
Wheeler sand.........	—1,075	225	200	a 350
Bartlesville sand......	—1,525	175	200	200

SHAMROCK DOME

	Elevation of crest	AMOUNT OF DIP	
		1½ miles west of crest	*¾ mile east of crest*
Surface beds....................	+1,125	135	60
Layton sand....................	— 325	325	250
Wheeler sand....................	—1,150	175	200
Bartlesville sand................	—1,550	325	250

MOUNT PLEASANT DOME

		Amount of dip			
	Elevation of crest	*2½ miles W. of crest*	*4 miles W. of crest*	*¾ mile S. W. of crest*	*¾ mile N. E. of crest*
Surface beds	+1,100	150	225	75	75
Layton sand	− 275	300	425	325	325
Wheeler sand	−1,100	350	475	325	400
Bartlesville sand	−1,450	350	b 475	325	400

ANTICLINE IN NORTHERN PART OF T. 16, N., R. 7 E.

	Elevation of crest	*Amount of dip ½ m. E. of crest*
Surface beds	+1,050	50
Layton sand	− 400	75
Wheeler sand	−1,325	50
Bartlesville sand	−1,700	100

a = part of vertical distance estimated.
b = part of horizontal and vertical distances estimated.
+ = above sea-level.
— = below sea-level.

These differences in the folding at different depths, of course necessitate variations in the interval between the sands on which the measurements were made. Thus, for instance, the interval between the Layton Sand and the Bartlesville Sand varies from 950 feet to 1,350 feet.

Apparently the thickness bears some definite relation to the folding. (Only a part of the variation is due to a regular increase from north to south in the thickness of the deposits.) If isochore lines (lines passing through points where the interval is the same) be drawn on the map, they tend to be concentric around the domes; the interval between the two sands being less at the center of each dome and increasing in all directions as we pass outward from the center.

Such conditions cannot be explained by original variations in the thickness of the deposits; nor by unconformities. One suggested explanation is the gradual growth of the folds during the accumulation of the deposits, but this also presents difficulties. The conclusion reached is that these differences in thickness have somehow resulted from the folding movements.

The Domes in the Cushing Field

Further particulars about the structures, in order from north to south, are as follows:—

The **Dropright Dome** occupies about 10 square miles, and has a closure of 125 feet. The elevation at the top of the dome, measured on the key-bed, which is the Pawhuska Limestone, would be 1,050 feet. From the crest of the dome to the bottom of the syncline, which lies 1½ miles northward, there is a fall of from 125 to 175 feet.

Observed on the Layton Sand, the general structure is similar to that of the surface beds; but the dome has a double crest, and the dip is steeper. To eastward there is a fall of 200 feet in half a mile.

On the Wheeler Sand the dome resembles that of the Layton Sand, but the dip on the east side is 100 feet greater in ¾ of a mile. The top of the dome, also, is broader and larger, and bears on its flanks several subsidiary dome-like structures.

On the Bartlesville Sand the dome has three crests; and there are various "bumps" which do not correspond to those found on the dome in the beds above.

The **Wheeler Saddle**, between the Dropright and Drumright Domes, is a trough over 30 feet deep. In the Layton Sand and the Wheeler Sand, which bear gas on the domes, there is oil in this saddle, but in the Bartlesville Sand there is water.

The **Drumright Dome** has an elevation of 1,025 feet on the surface beds, and a closure of 20 feet. The fall to the bottom of the saddle, to south of it, is only 20 feet. On the west side the dip of the surface beds is 225 feet in 4 miles, but the dip of the three oil sands below ground is about twice as steep. There are various differences in the shape of the dome in the sands.

The **Mount Pleasant Dome** has an elevation of over 1,100 feet on the Pawhuska Limestone, and is about 50 feet higher than the Dropright Dome, and 75 feet higher than the Drumright Dome. There is a closure of 75 feet.

To northward there is a fall of 100 feet in 1¼ miles to the bottom of a synclinal trough. On the south side there is a fall of 75 feet into the syncline. To westward the dip rapidly decreases on to the Wheeler Terrace.

On the sands underground, the structure is similar, but the dip away from the crest is steeper.

The **Wheeler Terrace,** which lies west of the Mount Pleasant Dome, is more pronounced in the underground beds than at the surface. There is little or nothing in the surface structure map to suggest that this area would be so productive.

The **Shamrock Dome** is the highest in the Cushing oilfield, the contours on the Pawhuska limestone attaining to 1,125, which is 25 feet higher than on the Mount Pleasant Dome. The closure is 90 feet.

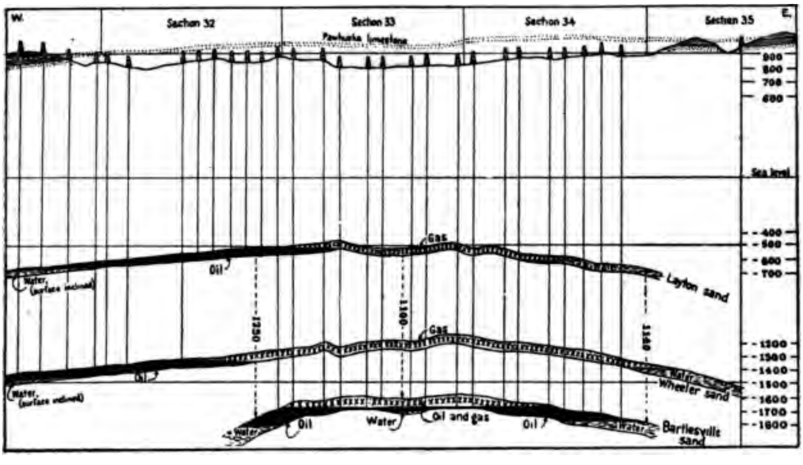
The dip into the syncline, to eastward, is 90 feet in 1½ miles. To westward the dip amounts to 175 feet in 2 miles, and in the next mile flattens out into the normal westerly dip of about 50 feet per mile.

In the three oil sands the crests of the dome are practically alike, but the dip to westward differs widely. In the surface beds it is 135 feet in 1½ miles; in the Layton Sand it is 325 feet in the same distance; in the Wheeler Sand it is 175 feet, and in the Bartlesville it is 300 feet. The dip to eastward is 250 feet in ¾ of a mile in the Layton Sand, 200 feet in the Wheeler, and 250 feet in the Bartlesville.

Distribution of Gas, Oil and Water in the Sands

The disposition of the oil and gas in these structures is very interesting, for it does not agree closely with the ideal hydrostatic arrangement, neither as regards gas, nor oil, nor water. The separation of the oil and gas is very imperfect, and the bodies of gas are not always at the highest places on the structure.

FIG. 19.



CUSHING OIL FIELD SECTION ACCROSS DRUMRIGHT DOME (after C.H.Beal.)

(Note.—Vertical Scale = 4 times Horizontal Scale.)

Distribution in the **Layton** *Sand*

In the Layton Sand the distribution of oil, gas and water does not, in detail, follow the anticlinal theory, except on the Dropright dome. On this dome there is a large area, about 1½ miles wide, which is occupied entirely by gas. Around it there is an irregular border, in which oil and gas occur together: and, outside of this, there is a fringe of territory in which oil only is found. Beyond this, again, there is water.

In the greater part of the field, however, the arrangement is different; for, except in a few places, there is no oil on the east side of the field; but a great body of gas extends from the water-line up the east flanks and over the domes, and for a considerable distance down the west flanks.

West of this gas area, farther down the west flanks, is an area containing gas and oil together; and beyond that again, there is a belt, ¼ to ¾ of a mile wide, containing oil only. This belt broadens out to 1½ miles in width in the Wheeler Saddle, which is occupied entirely by oil.

Neither the water surface nor the oil surface are level. The bottom of the gas body is unlevel, its elevation generally ranging from −550 to −450 in the Dropright Dome, and from −575 to —475 in the other structures. On the east side of these other domes the gas body nearly everywhere rests on water.

On the Dropright Dome (summit −400) the oil extends down the west slope in commercial quantity as far as −575. Down the north and northwest slopes there is oil as far as −650.

Around each of the other domes,—Drumright (summit — 500), Mount Pleasant (summit — 275),and Shamrock (summit −325),—the oil in places extends down as far as −625 or −650.

The water under the oil and gas in the Layton Sand has different altitudes in different parts of the field. Its surface is inclined. The contours of this water surface are only roughly concentric with the contours of the dome. They cross and recross the structure-contours repeatedly. The general dip of the water-surface is outwards from the dome: that is to say, the water surface dips in the same direction as the strata, but the angle is less steep. The contours of the water-surface can be drawn only for the belt of territory in which the wells entering this sand pass through gas or oil into the water—elsewhere there is either no water present or else there is no free surface, because the water is confined by the roof of the sand.

On the Dropright Dome the highest point determined on the water surface is −610, and the lowest point is −710. The maximum dip of the water surface on the northwest side of the dome, is 100 feet to northwestward in a little more than ½ mile.

West of the Drumright Dome and Wheeler Saddle, the highest and lowest points on the water surface shown on the structure map, are at −620 and −700; the inclination of the water-surface being 90 feet in 1 mile, directed westward away from the dome.

On the southwest side of the Shamrock Dome the water surface occurs between −575 and −600. Here the water is higher up the structure than anywhere else in the field.

Distribution in the **Wheeler** *Sand*

This sand is charged with a great quantity of gas and a smaller quantity of oil. The gas occupies all the east side of the field, all the domes, and a large part of the west slopes.

In the Dropright Dome this sand is wholly occupied by gas, except for a small area in the northwest part, where oil accompanies the gas.

In the other domes, down their west slopes, west of the gas, there is a discontinuous strip of territory containing oil and gas together, and west of this there is a border containing oil without gas.

The area with oil alone, consists chiefly of the Wheeler Terrace and a small strip of land west of the Shamrock Dome. (The elevations of the summits of the domes are:— Dropright −1,075, Drumright −1,150, Mount Pleasant −1,000, Shamrock −1,150 and −1,275.)

On the west side of the field, in places where the gas rests on oil, in some parts the plane separating them has elevation between −1,300 and −1,350.

On the east side, the gas rests on a water surface, whose elevation ranges from −1,300 to −1,400.

The oil, which lies practically wholly on the west side of the field, extends down the dip to −1,425 on the Wheeler Saddle, down to —1,475 on the Wheeler Terrace, and to - 1,450 southwest of the southern Shamrock Dome (summit - 1,275).

The water surface in this sand, as in the Layton Sand, is inclined everywhere away from the domes. The data for this sand are not complete, but a good group of 10 ft. water contours was drawn on the west side of the Wheeler Terrace, ranging from - 1,400 to - 1,460 feet, the maximum dip being 40 feet in ¾ of a mile. On the west side of the field the water stands at higher levels: - 1,330 to - 1,400 feet.

Distribution in the **Bartlesville** *Sand*

This sand is thick and variable, containing lenticles of shale and sand of different porosity. There are, therefore, many irregularities in the distribution of the fluids, and streaks of gas, oil or water sometimes are found apparently out of place.

Although the Bartlesville Sand contains important quantities of gas, there is no large area in which it contains gas exclusively. Gas, in company with oil, occupies the high parts of the domes and a portion of the slopes, especially the eastern slopes, down which it extends considerably farther than on the west slopes.

Frequently streaks of gas are encountered with a pressure of 1,000 lbs., or more, and some wells have given 50 million cubic feet in 24 hours. On the southeast edge of the Shamrock Domes there is about a square mile of ground in which gas occurs alone; and here the wells had a capacity of as much as 60 million cubic feet a day, with a pressure of over 1,000 lbs. per square inch.

Outside of the areas containing oil and gas together, there is a large area containing only oil. On the east slopes this is narrow, discontinuous, or absent; but on the west slopes it is ½ mile to a mile in width.

In this sand the petroleum does not extend so far down the dip as in the case of the other sands; and the Wheeler Saddle and Wheeler Terrace are occupied by water.

The oil extends down the north side of the Dropright Dome (summit at -1,525) to about -1,800, but on the west side the limit is about -1,600, and on the east side it varies between -1,650 and -1,800.

On the sides of the Mount Pleasant Dome (summit at -1,450) the Bartlesville oil extends down to depths of from -1,650 to -1,750.

On the west side of the field the lower limit ranges from -1,750 to -1,850.

The water surface could not be determined so completely as for the Layton Sand.

On the Dropright Dome the water surface on the north, west and east, ranges from -1,700 to -1,850. The maximum dip of the surface established is 80 feet in half a mile.

On the Wheeler Saddle and the Wheeler Terrace water occupies the Bartlesville Sand.

West of the Drumright Dome the height of the water ranges from -1,700 to -1,830. East of the Mount Pleasant

Dome the water surface was found at about −1,840, and also higher up at −1,740. Near Shamrock the figures are from −1,800 to −1,870.

Explanation of the Distribution of Oil and Gas

The unusual distribution of oil and gas in the Cushing field is explained as follows: The dominant structure is an anticline on a great monocline, the fold having a long west limb and a short east limb. The gathering ground, therefore, is practically all on the west limb. According to Mr. Beall:

"Gas first fills up the crest of the fold and acts as a barrier between the water on the east side and the oil migrating up the west limb. The oil, on account of its slower rate of movement through porous rocks, collects after the gas and forms a pool against the gas on the west or long limb."

Problem of the Water Surface

The investigation of the water surfaces in the Cushing field is the most complete that has been published for any oilfield. The main facts have been mentioned above. In Mr. Beall's words:

"The most important disclosure is the fact that the water surfaces upon which the oil and gas rest in the Layton, Wheeler and Bartlesville Sands, are not horizontal, and not only lie at different elevations on different sides of the domes but are also inclined away from the center of the upfolds, conforming roughly to the structure of the oil sand, but not dipping so steeply as the roof of the reservoir in which the oil and gas are contained."

Thus, the water surfaces in the three oil sands are very irregular in shape. They might be described as much-warped, inclined planes, everywhere sloping away from the folds.

"The water-line in the Layton Sand, that is the line representing the warped water surface, ranges in depth below sea-level, from about 575 feet at the south end of the field to about 750 feet on the west side of the Wheeler Terrace and Wheeler Saddle. On the sides of the Mount Pleasant Dome and on the east side of the Shamrock Dome this line rises much higher.

"The water-line in the Wheeler Sand around the Cushing structure is much more variable than the water-line in the Layton Sand; it rises at high as 1,250 feet below sea-level on the east side of the Shamrock Dome, and is found as low as 1,475 feet below sea-level on the west side of the Wheeler Terrace.

The water-line in the Bartlesville Sand around the Dropright Dome ranges from 1,650 to 1,800 feet below sea-level, which is about the same range observed in other parts of the Cushing field."

It is interesting that in each sand the water stands higher on the east and west sides of the domes than at the ends, which have a gentle dip. For instance, in the Layton Sand on the Dropright Dome the water comes up to –600 on the east and west sides, and –650 on the north side.

After much investigation it was considered that the inclination of the water surfaces was in existence previous to the drilling, though in some places there is evidence that the slope has become steeper as development proceeded.

No satisfactory cause for these facts was found, but they were attributed to:

"the forces that controlled the accumulation of the oil and gas, among which are the friction of low-dipping beds, the difference in the viscosity of oil and water, the difference in the porosity of the sands, the compressibility of gas, and the incompressibility of oil and water. It is also possible that the water in these sands was originally level, but that folding, subsequent to the accumulation of oil and gas, inclined the water surfaces."

Productivity and Structure

To study the relation of production to structure, the initial daily production of each well was marked on the maps. Lines were then drawn to separate the areas of high production from the areas of lower production. From these maps it is seen that the places of high production occur on the tops of the domes (except when those are occupied exclusively by gas) and they extend down the west slopes for a considerable distance in those parts where gas accompanies the oil in the same sand.

In the Layton Sand initial production of over 100 barrels a day was obtained in an area of 3 square miles. In the Wheeler Sand, also, wells starting at over 100 barrels a day were obtained in an area of 3 square miles. In the Bartlesville Sand an initial daily yield of a thousand barrels was found throughout an area of 11 square miles.

The "flowing life" of the big producers generally was short. Many wells which at first gave 3,000–10,000 barrels daily, soon declined to small pumping wells. For example, a group of wells, drilled in the early days of this field, which at first had an average daily output of 1,000 barrels each, were yielding in their fourth month an average of only 44 barrels a day each. A year later the same wells were giving only 11 barrels a day. Similar rapid decline has been the rule in this field, the chief causes being the reduction in the gas pressure, due to allowing immense quantities to flow freely to waste. (See Fig. 4.)

The output of the Cushing field reached a maximum in 1915, when during the month of April the daily production averaged 300,000 barrels. At the present time there is a production of 36,000 barrels a day.

Altogether, up to the end of 1919, the Cushing oilfield has yielded about 236 million barrels of oil, from an area of 32 square miles, which is equivalent to 11,500 barrels per acre.

(For further particulars, see Part VI, Chap. 5, Section B.)

CHAPTER IV

STRUCTURE IN THE GLEN FIELD

The Glen oilfield was studied by C. D. Smith, of the United States Geological Survey. The accompanying structure map is founded on Plate III of Bulletin 541.

The contours represent the top of the Fort Scott Limestone, and show 25-foot intervals. The dotted area is the productive territory.

No defined anticlines and no domes are revealed by this structure map, though it is seen that the monoclinal slope is "fluted" with ridges and furrows, having an east and west direction. The dip is somewhat steeper than usual, being about 50 feet per mile, and in places 100 feet per mile.

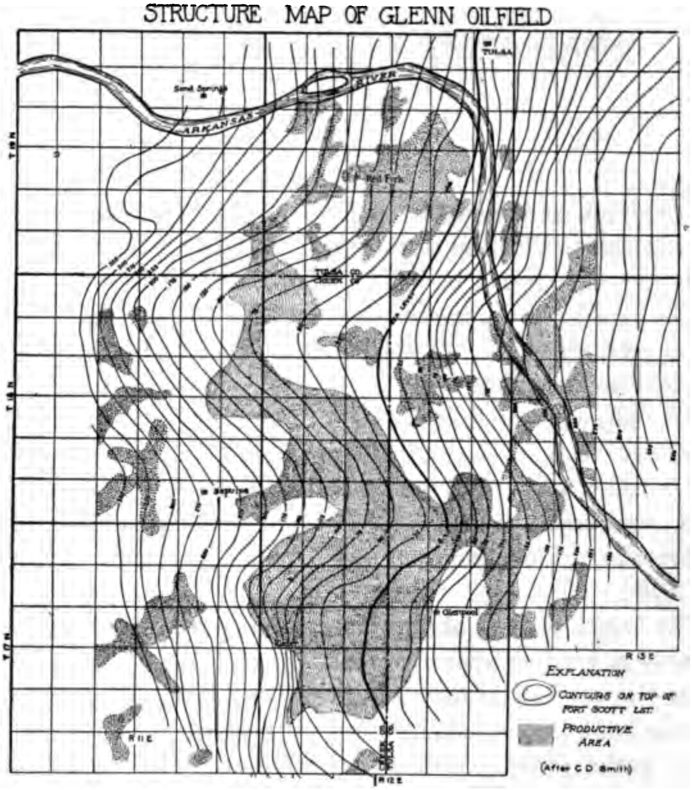
The main pool is about 8 miles long and, in the richest part, it is 4 miles wide. In this distance of 4 miles, the dip takes the oil sand downward a vertical distance of 200 feet. Throughout this slope the sand carried oil.

No satisfactory reason for this great oil accumulation is apparent from the map, and it is fairly safe to say that, had the structure been worked out before the discovery of the oil, this place would not have been selected by geologists as being particularly favorable.

It is considered by some, that the thickness and lenticularity of the sand is one of the principal factors in this case. The Glen Sand shows great variation in thickness, the extremes, according to the drilling records, being 124 feet and 10 feet. It appears to be thickest in the center of the pool.

But against this argument, is the fact that a number of

FIG. 20.



other sands, above and below, also carry accumulations of oil at the same locality. Indeed production has been obtained from no less than 12 sands in the Glen field. Not all of these sands are productive at any one spot, but throughout a large area there is oil, in quantity, in at least four of them.

The more important sands are:

Red Fork Sand: Thickness 10–30 feet. Large producer.	1,300–1,500 feet.
Glen. Sand: Thickness 90 feet. Great producer. May be the Bartlesville Sand.	170–1,800 feet.
Squaw or Taneha Sand: Thickness 10–50 feet. Considerable producer.	1,900 feet.
Rhodes or Dutcher Sand: Considerable producer. 50 feet above Morrow Limestone.	2,000–2,025 feet.
Mounds Sand:	2,390 feet.

The development commenced in 1906, and from March, 1907, to May, 1911, the output was from 1 to 2½ million barrels a month, the maximum being reached in October, 1907. Many wells at first gave 1,000–2,000 barrels a day.

The field is now in its decline but is still producing nearly ½ million barrels a month.

The total output up to the end of 1919, is about 153 million barrels of oil from an area of 30 square miles. Thus the average yield per acre has been 8,000 barrels, though in some parts 16,000 barrels per acre have been obtained.

Gas in great quantity was found above, below and within the oil sands. About 4% of the wells were gas wells, many of them having initial daily capacity of 20–60 million cubic feet.

(For further details, see Part VI, Chap. 5, Section B.)

CHAPTER V

STRUCTURE IN THE BRISTOW QUADRANGLE

The structure of this district, in Creek County, Oklahoma, was mapped by A. E. Fath of the Geological Survey, and was published in Bulletin 661-B, in 1917.

The structure map of this area (150 square miles), is on a scale of 1 mile to the inch, and the structure contours are drawn on the base of the Tiger Creek sandstone, at 10-foot intervals.

This territory is of particular interest, as it lies between the great oilfields of Glen and Cushing. Fourteen test holes had been drilled, with very little success, at the time when the survey was being undertaken.

The entire area is occupied by the Pennsylvanian rocks, their outcrops trending across the map in a N. N. E. direction. The outcrop of the Elgin Sandstone crosses the west end of the map: and the outcrops of the Tiger Creek Sandstone and Dewey Limestone cross the east end of the map. The average dip is about 50 feet per mile, or a little more than half a degree.

There are a number of small faults, having a N. N. W. direction, which cause numerous interruptions in the structure contours. They are normal faults with downthrow on the west side. The largest displacement is 130 feet and the greatest length is 3¼ miles.

The structure map shows this district to contain far less folds than many other parts of the State—far less for instance than in Osage County. The structure contours are more nearly parallel, and less "wavy" than usual. There are, however, a number of slight "noses," a few faulted anticlines or domes, and one or two small basins with closure.

CHAPTER VI

STRUCTURE IN THE GARBER FIELD

A structure map of this new oilfield, by D. Hager, B. C. Bell, and H. Haworth, Jr., was published in 1917 (Oklahoma Geological Survey, Bulletin 19, Part II).

The rocks at the surface belong to the Permian Red Beds, and structure is difficult to prove. The map indicates an elongated dome with closure of 100–150 feet.

The dip on the east side, which is the steepest, is 200 feet in 2 miles. The early wells were drilled on the dome in accordance with geological advice, and there is now a large production at 1,000–2,300 feet.

The principal productive sands are:—

Hoy Sand	at	900 feet.
Hotson Sand	at	1,500 feet.
Belveal Sand	at	1,750 feet.
Billings Sand	at	2,100 feet.

The exploitation commenced in 1916 and the production for August, 1919, was 10,470 barrels a day.

(For further details, see Part VI, Chap. 5, Section B.)

CHAPTER VII

STRUCTURE IN THE PONCA CITY FIELD

The Ponca City oil and gasfield was studied by D. W. Ohern and R. E. Garrett, and a structure map was published in 1912 (Oklahoma Geological Survey, Bulletin 16). A more complete structure map of this field and the other fields of Kay County, by L. E. Trout, was produced by the Oklahoma Geological Survey in 1917 (Bulletin, 19, Part II). Several anticlines are shown, with axes trending S. W. or S. S. W.

The Ponca City dome is long and narrow with a closure of 60 feet or more, and has the east side steeper than the west side. An east dip of 90 feet in half a mile is proved by the drilling.

Most of the wells are on the dome, but there has been a considerable production, especially of gas, from wells situated on the axis of the fold, north of the closed dome.

The rocks at the surface in this district belong to the Lower Permian, and the structure contours are drawn on the Herrington Limestone.

The chief gas sand was at about 550 feet below the Herrington Limestone. It is light colored, coarse and porous, with thickness of 25–50 feet. Most of the early wells were drilled no further than this sand—their capacities ranging up to 5 million cubic feet. In 1906–1908, 178 million cubic feet of gas were sold for household use.

Subsequently, deeper drilling led to the discovery of several productive oil sands and other gas sands. Wells in the sand at 1,500 feet have produced as much as 500–700 barrels of oil a day.

During 1919 an important sand at 3,900 feet has been exploited. Several of the deep wells have come in at 1,000—3,000 barrels a day.

The output for August, 1919, was 3,250 barrels a day.

(For further details, see Part VI, Chap. 5, Section B.)

CHAPTER VIII

STRUCTURE IN THE MERVINE FIELD

The Mervine field, in the east-central part of Kay County, lies 6 miles southeast of Newkirk, and is often referred to as the Newkirk oilfield, though it is better to reserve that name for the group of old gas wells near the city.

A structure map of this field by L. E. Trout, was published by the Oklahoma Geological Survey in Bulletin 19, Part 2.

The contours are drawn on the Herrington Limestone at 20-foot intervals. They show the oilfield to be situated on an elongated narrow dome, with a closure of 80 feet in a length of 3 miles. The steepest dip is on the east side, being about 150 feet in one mile. This dome is on an anticline which has been called the Newkirk Anticline.

The axis of this fold is indicated on the structure-map by a crooked line, extending 12 miles southwestward from the dome, to within a mile of Ponca City. The structure contours show the anticline to pitch downward to the southwest about 300 feet in 12 miles.

The productive sands are:—

Elgin Sand, at 900 feet.
  Initial daily yield of the better wells, 100–500 barrels.

Deep Sand, at 3,100 feet.
  Initial daily yield of the better wells, 500–1,000 barrels.
  Initial daily yield of gas wells, 30–40 million cubic feet.

Drilling on the dome began in 1913, after the structure had been determined by the Oklahoma Geological Survey.

The first well came in at 100 barrels a day, and in April, 1914, the field had an output of 2,500 barrels a day.

There was much development in the deeper sands during 1918; and in May, 1919, there was a production of 4,300 barrels a day.

Near the northeast corner of the county, about 6 miles northeast of the Mervine field, another dome lying on the same general line of folding, was mapped, and is also shown on the above mentioned map.

The contours are drawn at 10-foot intervals, on the Fort Riley Limestone. They indicate a well-developed, elongated dome, with closure 40 feet. The southwest side is the steeper, having a dip of about 80 feet in 1½ miles, into the bottom of a synclinal basin.

One deep well was drilled on this dome, but although the structure appears so favorable, no profitable amount of oil was found.

Another smaller but steeper dome, of 40-feet closure, occurs 3 miles northeast from Newkirk.

CHAPTER IX

STRUCTURE IN THE BLACKWELL FIELD

A few miles northeast of Blackwell, two anticlines, parallel and side by side, were mapped by the Oklahoma Geological Survey, and are represented on Plate XXIII in Bulletin 19, Part 2.

The axes have a N. N. E. direction, and the folds, like the others in Kay County, pitch southward.

The structure contours are drawn on an unnamed limestone, at 10-foot intervals, and show the dip on either side to be 50–80 feet per mile. Several domes of small closure are shown on the western anticline.

The Blackwell oil and gasfield has a length of 11 miles from north to south. The productive area does not conform at all closely to the surface structure—much of it being a mile or more down the west flank of the principal fold.

The oil production was obtained first from a deep sand, at 3,300–3,400 feet, in which a number of wells had initial production of 1,000–3,000 barrels a day.

The exploitation of this deep sand commenced in 1914 and in 1917 the output reached 10,000 barrels a day, and then declined.

During 1918 the development was mainly in a sand at 1,800 feet, in which excellent results are being obtained. At the end of the year there was a yield of 6,000 barrels a day. In the latter part of 1919 the output was about 4,000 barrels a day.

The field is remarkable for the number of its gas sands. The early wells were drilled for gas, in 1904 and 1905. These produced from a sand at 750 feet, and had capacities up to 5 million cubic feet a day. Later, when the deep drilling commenced, a number of more prolific gas sands were encountered. In one well eight separate gas sands were found, each yielding from 1 to 30 million cubic feet a day. The daily capacity of this well was 116 million cubic feet.

There is now a large production of gas from the deep wells, and several plants are in operation extracting gasoline.

CHAPTER X

STRUCTURE IN THE BOYNTON FIELD

The Boynton oilfield, in Muskogee County, is situated on the top of a pronounced dome structure.

A structure map, by F. J. Fochs, is published in Bulletin 19, Part 2, of the Oklahoma Geological Survey.

The dome is elongated in a northeast direction and has a closure of about 100 feet. At the western end of it there are dips to westward and to northwestward, of 300 feet in little more than 2 miles. At the eastern end, the inclination is more gentle, and the beds dip 130 feet in 2 miles down into a syncline.

The productive ground conforms closely to the structure, being almost wholly within the area of closure.

The principal oil sand is the Boynton Sand, at 1,500–1,600 feet; but oil has been found in at least three deeper sands.

Gas sands were found at 825, 1,100, 1,400, and 1,800 feet; and some gas wells had initial capacity of 5–10 million cubic feet.

The field was opened in May, 1914, and in 1915 the output rose as high as 7,500 barrels a day, but it had declined to 1,800 barrels a day, at the end of 1919.

CHAPTER XI

STRUCTURE IN THE BILLINGS FIELD

A structure map of this district, by A. E. Fath, was published in 1916 by the Geological Survey (Bull. 641-E). This map, on a scale of ½ inch to the mile, shows the surface of a prominent limestone seam by means of structure contours at 10-foot intervals. The evidence is incomplete, but is sufficient to prove a strong anticline with N. E. direction.

On this anticline there is at least one dome, with closure probably 40 feet. The dip on the east side of this dome is comparatively steep, amounting to 130 feet in a little more than ½ mile.

Since the map was made, an oilfield has been developed on this anticline. There are now a number of oil and gas wells on the dome, and also farther north along the fold.

The surface is occupied by the red rocks of the Upper Permian, but the production is from the Pennsylvanian—principally the Billings Sand, at 2,100 feet.

In 1917 and 1918, some of the wells had initial production of 2,000–3,000 barrels a day and the daily output rose to 15,000 barrels; but by the end of 1919, it had declined to 2,200 barrels.

CHAPTER XII

STRUCTURE IN OSAGE COUNTY

Structure Surveys Published

A structure survey of almost the whole of Osage County, Oklahoma, has been made by the United States Geological Survey in the past few years.

The greater part of this large county, known as the Osage Indian Reservation, has long been withheld from exploitation, and it is expected that many rich oilfields are awaiting the drill. In some districts in the east part of the reservation, where development had been permitted, there are already a number of good fields.

The first part of this extensive survey work was published in Bulletin 641-B, which contains a complete structure map of the Foraker Quadrangle (about 140 square miles), on a scale of 1 inch to the mile. The structure contours are drawn on the top of the Foraker Limestone, with 5-foot intervals.

The next publication was Bulletin 691-C, containing a similar structure map of the Pawhuska Quadrangle (140 square miles), on a scale of ½ mile to the inch, with structure contours at 10-foot intervals on an imaginary stratum 200 feet below the Oread Limestone.

These were followed by Bulletin 686, which is being published in parts, of which 22 have already appeared. These works include some 30 structure maps of various areas mostly on a scale of 2 inches to the mile. The contours are drawn on a number of different horizons, and the intervals are generally 10 feet, and in some cases 5 feet.

Altogether, this beautiful series of maps portrays, in fine detail, the geological structure over an area of 2,000 square miles.

The Regional Structure

The rocks exposed at the surface belong to the Pennsylvanian and Lower Permian. Many different outcropping limestones and sandstones were used as key horizons in the geological mapping of this large territory.

From the maps, referred to above, it is seen at a glance that the general structure is a monocline dipping towards the west at an average rate of 30 to 35 feet per mile. The dip, however, is far from uniform. In some localities, the beds dip westward at double or triple the average rate, and these steepenings are compensated by areas where the westward dip is very low.

The conditions are described in a picturesque manner by K. C. Heald,* as follows:—

> "If the earth and rock were all stripped from above the key horizon on which the structure contours are drawn, a broad, flat, westward-sloping plain would be exposed to view. The surface of this plain would be marked by low, smoothly rounded hills or knolls; broad, smooth-crested, westward-pitching ridges; short shallow valleys opening to the west and broadening at their mouths until they merge into the westward monocline of the regional structure; and a few small oval depressions. The evenness of the surface would be further interrupted by a few low, inconspicuous—almost vertical fault scarps trending in a general northwesterly direction."

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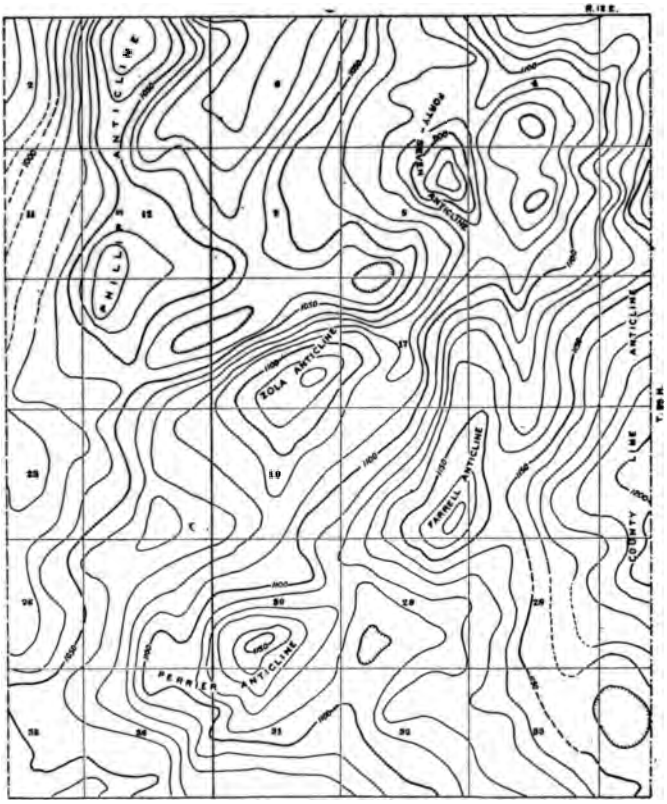
* K. C. Heald, Bulletin 691-C, p. 77.

The Local Structures

The minor folds on the monocline are very numerous—they are distributed plentifully all over the area so that no part of the monocline is plain.

FIG. 21.



STRUCTURE IN OSAGE COUNTY T. 25. R. 11 AND 12.

(*After O. B. Hopkins, U. S. Geol. Surv.*)

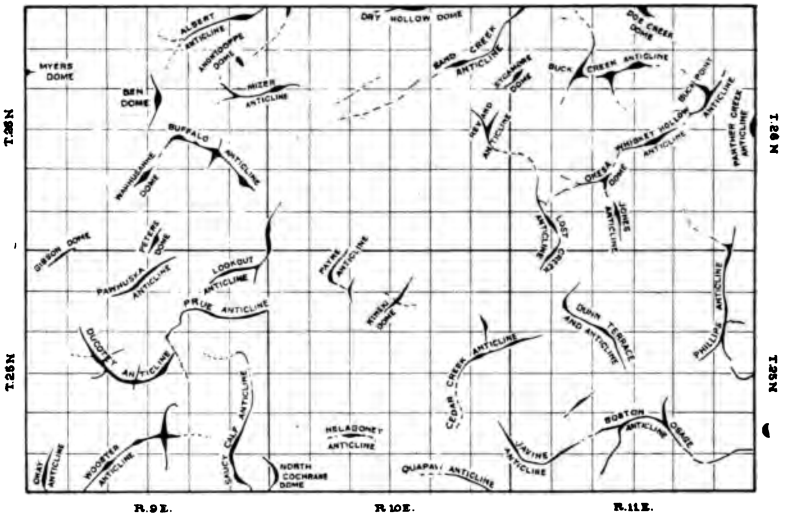
There is a general tendency for the folds to follow a N. E. or N. N. E. trend, but there are also many other directions. (See Figs. 21 and 22.)

The anticlinal crests are traceable generally for lengths of 1–5 miles, and the distance from one crest to the next is usually 1–3 miles.

There are a number of small faults which almost all have a northwest direction.

Fig. 22.

ANTICLINES IN A PART OF OSAGE COUNTY



(*After U. S. Geol. Surv., Bull. 686.*)

The structures are conveniently summarized on "sketch maps," showing the crests of the anticlines and domes (See Fig. 22) They are clearly represented by irregular curved lines with occasional branches.

The folds consist of irregular domes, anticlines, "noses" * and terraces, with intervening basins, synclines and depressions. Altogether about 200 well-marked domes and anticlines are shown and named upon the detailed structure maps.

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* A nose is a small anticline, pitching gently down in the direction of the general monoclinal dip, and thus causing a nose-shaped protuberance on the contours, pointing down the dip.

Most of these structures in the Osage County are comparatively small. The shapes are irregular but, more often than not, there is an elongation in a north or northeast direction. About half of the folds have a closed structure. The closure commonly is 30–40 feet, but in some cases it is as much as 50 or 60 feet and rarely more. The maximum dip on either side of the folds usually is 70–90 feet per mile, and seldom exceeds 100 feet per mile.

One of the largest folds in the Osage County is the Birch Creek Dome, with a closure of 125 feet which covers an area of 4 square miles. On its southwest side, there is an exceptionally steep dip, of about 200 feet in a mile. This dome is partly drilled and is already a proven oilfield.

Probably the most regular shaped fold in the county is the Bald Hill Dome, which also is one of the largest. This is an almost circular dome with a closure of 80 feet. The dip to the north-northwest is 120 feet in one mile, and in the other directions, about 70 feet in a mile. There is a developed oilfield on this dome.

Another very symmetrical structure is the Myers Dome—an elliptical dome with a closure of 80 feet, over an area of 1½ square miles. The dip on the north and south sides is 90–100 feet in a mile. A gasfield has been opened on this fold.

About 30 of the above-mentioned domes and anticlines are already productive, and most of the remaining folds are as yet untested.

In a few instances, there are folds upon which wells have been drilled without success. In one case, there is a small productive oilfield located where the surface rocks have a distinct synclinal structure. Two or three producing fields are on terrace structures. But with the above exceptions, practically all of the developed oilfields in the county are on folds.

The present production is principally from sands near the base of the Cherokee formation, which are generally termed Bartlesville Sand.

Many wells in this sand, of 1,500–2,000 ft. depth or less, have had initial production exceeding 1,000 barrels a day. Other productive sands are known as the Tucker, the Burgess, the Layton, the Wheeler, the Squirrel, the Peru, and the Oswego Lime (Fort Scott Limestone).

The Osage country is interesting in that oil and gas production is found also in the Mississippian. Thus in the Hominy oilfield there are wells giving several hundred barrels a day, from sandy horizons 5–300 feet down in the Mississippi Lime, and in other districts there are wells yielding 5–30 barrels a day. This cherty limestone formation, which is about 350–400 feet thick, is supposed to be the same as the Boone Chert—but the correlation is not quite certain.

The Osage has increased its output largely in the past two years, and is now one of the important contributors to the Mid Continent production. The yield in October, 1919, was 42,000 barrels a day.

CHAPTER XIII

STRUCTURE IN SOUTHEAST OKLAHOMA

A district of sharper folding, in the southeast part of Oklahoma, was studied by J. A. Taff and G. I. Adams, of the United States Geological Survey (21 Annual Report, 1900, Vol. 2, p. 257, etc.).

In this work the folds have been readily expressed by ordinary geological mapping, without the use of structure contours.

These structures occupy a strip of country about 35 miles wide, bounded on the south by the Ouachita uplift, and bounded on the north, approximately, by the Canadian River. (See maps, Fig. 1 and Fig. 5.) (See Part IV.)

In this area the strata have been thrown into a series of fairly steep, narrow folds, having directions roughly parallel with the border of the uplift mass, which has a W. S. W. trend. The axes of these anticlines and synclines are shown on a geological map (Plate XXXVI), some of them being traced continuously 50 miles, or more. In general, the anticlines are unsymmetrical with the steeper dip on the north side.

As we proceed northward in this strip of territory, the folding becomes less intense and, at length, gradually dies out in the normal monocline with a gentle westerly dip. But southwards the folding increases in intensity as the Ouachita Mountains are approached; some of the southernmost anticlines being overfolds.

About eight miles from the margin of the uplift there is a great overthrust fault, known as the Choctaw fault, which is traced for a length of 120 miles. The rocks on the south side of the fault have ridden up over those on the north side with vertical displacement of several thousand feet.

The Pennsylvanian System is very thick in this district, consisting of some 15,000 feet of shales and sandstones, with many coal beds in some parts, and thick conglomerates. (See Part VI.)

The coals, in this more sharply folded and compressed territory, are superior to those in northeast Oklahoma and eastern Kansas, being richer in fixed carbon and containing less volatile matter.

Oilfields have not been found in this area, but some useful gasfields have been developed. These facts are in accordance with the law established by Dr. White.

The gasfields are situated generally on the crests of the folds,—the Poteau Anticline, the Savanna Anticline, the Coalgate Anticline, the Kinta Anticline, etc. Some of them are dealt with in Bulletin 541 B, by C. D. Smith, of the United States Geological Survey.

The Quinton-Kinta wells had capacities up to 20 million cubic feet and pressures as high as 700 pounds.

The Poteau wells, near the Arkansas boundary line, had capacities up to 18 million cubic feet a day, and pressure 412 pounds.

The Fort Smith wells, which are in Arkansas, could yield 4 million cubic feet a day, and had pressure 280 pounds.

The recent wells at Kibler in Arkansas, came in at 5–25 million cubic feet and showed a pressure of 285 pounds.

CHAPTER XIV

STRUCTURE IN THE HEALDTON FIELD

The structure of the Healdton oilfield was determined from the well records by C. H. Wegemann and K. C. Heald, of the United States Geological Survey. Their structure map was published in 1915, in Bulletin 621 B. Since that date, the field has been extended southward beyond the confines of the map.

The accompanying plan (Fig. 23) is founded on the above-mentioned structure map, but shows also the area which has now been developed. The contours are at 20-foot intervals and represent the form and elevation of the main oil sand relative to sea-level.

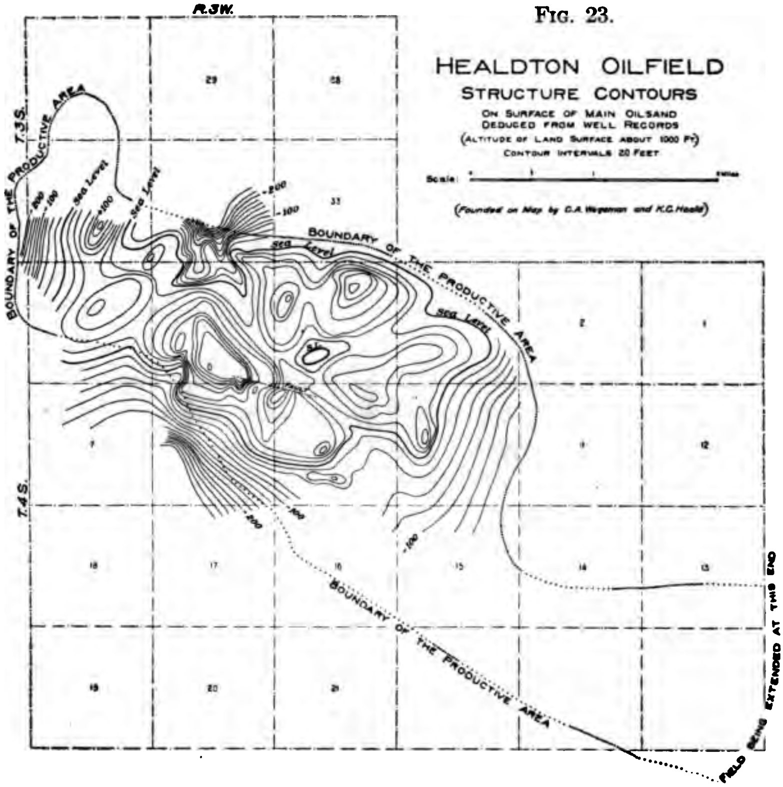
In most of the country occupied by the Permian deposits, the strata are very slightly inclined: but the Permian beds which lie around the uplift masses in southern Oklahoma, and which perhaps once completely covered these masses, are slightly arched and domed, as a result of the continuation of the movements in post-Permian times. Thus, these beds dip outward away from the uplifts, and in the space between the Wichita and Arbuckle uplifts they dip gently away to the north and to the south, on either side of the axis of the movements, in anticlinal form.

The Healdton oil pool lies southward from this general anticline, at a distance of 12 miles southwest from the west end of the Arbuckle Mountain uplift.

The developed field s about 8 miles in length, and has a width varying from 1 to 2 miles. A large part of this area lies on an irregular dome structure.

The surface in the oilfield is about 1,000 feet above sea-level, and there is nothing in the topography to indicate the dome.

FIG. 23.


HEALDTON OILFIELD
STRUCTURE CONTOURS
ON SURFACE OF MAIN OILSAND
DEDUCED FROM WELL RECORDS
(ALTITUDE OF LAND SURFACE ABOUT 1000 FT)
CONTOUR INTERVALS 20 FEET
Scale:
(Founded on Map by C.A. Wegeman and K.C. Heald)
R.3W.
T.3S.
T.4S.
BOUNDARY OF THE PRODUCTIVE AREA
BOUNDARY OF THE PRODUCTIVE AREA
BOUNDARY OF THE PRODUCTIVE AREA
Sea Level
Sea Level
Sea Level
Sea Level
-200
-100
+100
-200
-100
-200
-100
-100
29
28
33
2
1
7
12
18
17
16
15
14
13
19
20
21
FIELD BEING EXTENDED AT THIS END

The dip on the flank of the dome is rather steeper than is usual in the Mid Continent oilfields, in some places amounting to 300 feet in half a mile. In the top of the dome the main oil sand has an elevation of about 180 feet.

Inside the zero structure contour (oil sand at sea-level), the whole area apparently is productive, regardless of the numerous subsidiary anticlines and one depression. But the boundary of the oil pool does not by any means coincide with any contour; for though in some parts, the zero contour (sea-level) is the approximate limit to the production, in other parts, the oil in the sand extends down the dip to −250 feet, or lower.

Oil and gas are found in many sandstone seams in the Red Beds, but the three main sands occur in a zone about 250 feet thick, whose top lies at a depth of about 1,000 feet. The structure contours were drawn upon the second of these sands.

From the highest of the three oil sands there is a great production of gas, the initial capacity of most of the wells ranging from 20 to 40 million cubic feet a day. There is also some oil in this sand, lower down the dip.

The second sand is the principal oil sand. The best wells in it have come in at over 5,000 barrels a day.

The third sand also is highly productive. The oil is rather heavier than in the sand above.

Below these oil sands, which are entirely within the "red beds," deeper wells have encountered thick beds of dark shale and limestone, which probably belong to the Pennsylvanian.

The source of the oil is an interesting problem. The red beds contain very little organic matter, though plant remains and the bones of land animals are found occasionally. Many geologists consider that the oil has entered the red beds from the Pennsylvanian.

The specific gravity of the oil varies from 29.27 Be to 33.93 Be. Besides being heavier, it is also darker than the oil from the fields which produce from the Pennsylvanian.

The field was discovered in 1913, and the maximum yield was in 1917, when there was an output of 22½ million barrels.

Subsequently there has been a rapid decline, and in August, 1919, the production was 35,400 barrels a day. Altogether up to the end of 1919, the Healdton oilfield will have yielded 126 million barrels of oil from an area of about 13 square miles. (For further particulars see Part IV, Chap. VI, Section B.)

CHAPTER XV

STRUCTURE IN THE LAWTON FIELD

The Lawton oil and gasfield (Comanche County) is 8
les southeast of the southeast end of the Wichita Moun-
ns, situated on the axis of the Wichita-Arbuckle Uplift,
ng which the Permian deposits are slightly arched.

A structure map by C. H. Wegemann and R. W. Howell
s published in 1915 (Bull. 621 G).

This shows the oil and gas wells to be on an irregular
ne, on a general anticline. The dome has a flat, wide
, with closure of 20–30 feet; but away from the area
closure, on the flanks of the anticline, the dip is about
) feet per mile.

The rocks at the surface are the red beds of the Permian.
tween the oilfield and the mountains there are a number
asphaltic outcrops and some oil seepages. Some asphalt
arries have been worked.

In 1916 there were 50 producing wells, giving from 10
40 barrels of oil per day. The oil comes from a shallow
d at 400 feet and a deeper sand at 800–1,000 feet. At
e end of 1917 there was a production of 125 barrels a day.

CHAPTER XVI

STRUCTURE IN COTTON COUNTY

A structure map of the south part of Cotton and Tillman Counties, by M. J. Munn, was published in 1914 (Bull. 547).

This district is along the south border of Oklahoma, immediately north of the Electra-Burkburnett oilfields of north Texas.

The beds occupying the surface are red rocks of Permian age (Wichita formation).

The map shows some long, continuous folds, trending east southeast, and bearing domes of 20 or 30 feet closure, in several places. The folding is very gentle, the steepest dips being only about 60 feet per mile.

Oil production has not yet been developed in this district, but in the northeast part of the county a new field was being opened up, during 1918. Some of the wells came in at 200 barrels a day. As the depth of the wells is 2,300–2,500 feet, it is thought that the oil is in the Pennsylvanian.

CHAPTER XVII

STRUCTURE IN THE LOCO GASFIELD

A structure map of this small gasfield (Stevens County), which is 10 miles northwest of the Healdton oilfield, was made by C. H. Wegemann, and was published in 1915 (U. S. Geological Survey Bulletin 621 C). This map is on a scale of 1 inch to the mile, and the surface of the main gas sand is shown by contours at 20-feet intervals.

The wells are on an anticline whose axis has a northwest direction. They are not on the highest part of the crest, but are on a saddle between two areas of closure. The dip on the northeast side of the fold is 160 feet in a little more than one mile.

The rocks at the surface are red beds of the Permian. South of the gas wells there are many outcrops of asphaltic sandstones, which have been exploited on a small scale. Some wells in their vicinity yielded a few barrels of heavy oil.

The principal gas sand is within 250 feet of the base of the Permian, and is reached in the wells at 650–750 feet. The capacity of the wells is from 6 to 20 million cubic feet per day.

Showings of oil have been found at greater depth, probably in Pennsylvanian beds.

CHAPTER XVIII

STRUCTURE IN THE DUNCAN GASFIELD

This small oilfield (in Stevens County) lies about midway between the Wichita and Arbuckle uplift masses, a few miles north of the axis.

A structure map by C. H. Wegemann was published in 1915 (U. S. Geological Survey, Bull. 621 D).

These few wells are on the crest of a sharp anticline, trending north and south. The fold pitches northward and is steeper than usual, having a dip on either side of about 350 feet in one mile.

The surface rocks are red beds of Permian age. The gas sand is about 900 feet above the base of the Permian, and lies at a depth of 800–900 feet.

The capacity of the wells is 3–18 million cubic feet per day.

CHAPTER XIX

STRUCTURE IN NORTH AND CENTRAL TEXAS

Hundreds of structure surveys have been in progress in this region during the past two years, but the maps are the property of the oil companies and very few of them have been published. In various journals, however, general papers on the subject have been printed—(articles by D. Hager, W. E. Wrather, M. G. Cheney, W. E. Pratt, and others—). The following information is gathered largely from such sources.

The great development in this part of Texas has taken place mainly during 1918 and 1919. Previous to this time the older fields of Electra and Petrolia were on the decline, and the oil in the Bend formation had not been discovered. (Details of the history, development, stratigraphy, etc., have been given in Part VI, Chap. 4, Section E and Chap. 5, Section E, and Chap. 6, Section C.)

The opening of the rich pool at Burkburnett, in the Pennsylvanian, and the discovery of the deep oil in the Bend formation at Ranger, Desdemona, etc., led to such rapid exploitation that the north and central Texas production has quickly risen to ¼ million barrels a day (Sept., 1919),—which is considerably more than the output of Oklahoma.

Oil is obtained from each of the following five formations. (For details of the stratigraphy, see Part VI.)

Permian	Wichita or Albany
Pennsylvanian	Cisco Canyon Strawn
Mississippian	Bend

In north Texas (Burkburnett, etc.) there is a large production from the Pennsylvanian, chiefly at 1,800–2,000 feet, and also a small yield from shallow sands in the Permian. But in north-central Texas (Ranger, Desdemona, etc.) the main output is from the Bend formation of the Mississippian, at depths of 3,000 feet or more, whilst a small quantity is obtained also from the shallower horizons in the Pennsylvanian. The principal production is from the sources indicated below. (For further particulars, see Part VI, Chap. 4, Section E.)

Field	*Formation*	*Depth*	*Daily Output*
Electra-Burkburnett	Canyon	1,800	95,000
Ranger	Bend	3,450	65,000
Desdemona	Bend	2,750	50,000
Breckenridge	Bend	3,300	39,000

The **Regional Structure** has been discussed in Part IV and Part VI, Chap. 4, Sec. E. (See Fig. 9.) It was shown that the Pennsylvanian deposits lie in the form of a monocline which is the continuation of the Prairie Plains Monocline of Kansas and Oklahoma.

The strike is north-northeast in the main part of the area, but turns more to the northeast or east-northeast in the north of Texas. The dip is to the westward or northwestward at 40–80 feet per mile.

In the Bend formation the regional structure differs from that in the overlying Pennsylvanian. These Mississippian deposits have been slightly folded to form a gentle broad anticline, known as the Bend Arch. (For structure map, see Fig. 9.) This fold extends northward from the Llano-Burnett uplift mass towards the Oklahoma border. The dip on either side is about 50 feet per mile, and the axis pitches to the north at 30 feet per mile.

The **Local Structures,** which determine the positions of the oil pools, are the chief subject of this present chapter.

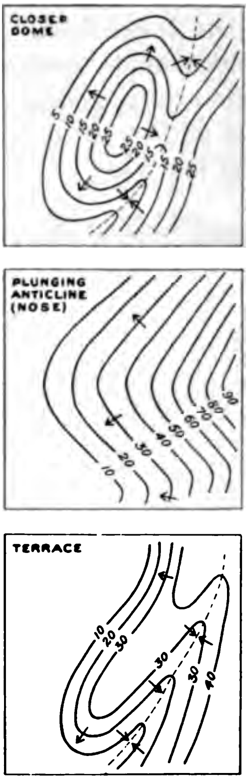
In this region these local structures are numerous but are very slight. At the surface they are detected by accurate instrumental survey. As found in the exposed Pennsylvanian beds, they are slight "noses," terraces, and domes. Not all of the structures bear oil, but almost all of the oil-pools are on structures.

The *Noses* are faint wrinkles or undulations, having their length at right angles to the strike,—or in other words they are very slight folds plunging down the dip. The downward plunge of the noses varies from 10 to 200 feet per mile. Their height rarely exceeds 100 feet, and their length generally is not more than a few miles—though in one instance a length of 15 miles is known. Frequently several noses occur in line, across the dip. This type of structure is the commonest, and is found in most of the oilfields. Good examples occur in the Breckenridge field and also southeast and southwest of Electra.

The *Terraces* have their greatest dimension parallel to the strike of the monocline. There is a spreading of the contours to form a terrace, and often subordinate noses lie on it. Sometimes the terraces are a number of miles in length, and frequently several terraces occur in line along the strike. There are good examples in the Ranger field.

The *Domes* or closed structures as much less common than the noses and terraces. In fact any dip directly opposite to

FIG. 24.



Structures Typical of Oilfields,
NORTH CENTRAL TEXAS
(after Dorsey Hager)

that of the monocline is rare, and consequently, completely closed structure seldom occurs. Even closures of as little as 5 or 10 feet are considered important.

One of the interesting features of the region is the discordance between the local structures found at the surface and those proved at depth.

Most of the large companies now employ sub-surface geologists in addition to the ordinary geological surveyors. These sub-surface geologists devote their attention to the evidence afforded by the drilling, and thus they work out surface contours on the oil-sands or other distinctive horizons encountered by the drill.

In general it is found that at depth the local folding is much steeper than it is at the surface, and reversal of dip is more frequent. "Folds in the surface beds in many cases reflect the more acute folding in the Bend Series." Thus south dips of 100 feet at the surface overlie dips of 200 feet in the Bend; and terraces and noses are found at the surface over closed structures in the buried rocks.

On the other hand, in some places there are apparent folds in the surface beds which probably have no counterpart in the beds which lie deep beneath.

In the sub-surface structures it is found that the fluids are arranged in the regular order prescribed by gravitation,—and the oil-pools are generally in the high points of these folds.

The folds at the surface, however, differ not only in shape from those found at depth, but usually they also are removed laterally—often in an up-dip direction. Consequently it is not possible, by means of the surface-structure, to locate exactly the positions of the oil-pools in the Bend formation which lies unconformably beneath.

But although the oil-pools do not generally underlie the tops of the surface folds, the producing fields are strikingly associated with areas of surface-folding; and nowhere has production been found on the normal monocline at a distance from such local folding.

In the **Ranger** field the production is connected with a large strike-terrace, with the usual superimposed noses. The large wells are on the down-dip edge of the terrace,—farther down than would have been expected from study of the surface terrace. In the underground beds, however, these wells are situated fairly high on the structure.

Near **New Caddo,** in Stevens County, the production is associated with pronounced surface folding, but is not confined to what would appear to be the favorable area.

The **Desdemona** field was located entirely by geological discovery of a surface-fold.

The **Breckenridge** field is associated with a prominent nose, but the best wells are far down the crest of this surface-fold. At depth, in the Bend Series, however, these wells are high on the structure.

In the above mentioned fields the production is from deep wells in the Bend formation. In the following, it is from comparatively small depth, in the Pennsylvanian.

In the **Electra-Burkburnett** field the surface structure seems to be strike terraces, along an E. N. E. direction. The production is mainly on the north side of the general terrace.

At **Petrolia** the structure is generally described as a dome.

The **Moran** field is associated with a small terrace.

The **Strawn** field is on small noses.

The shallow **Brownwood** field appears to be on a terrace.

CHAPTER XX

STRUCTURE IN THE PETROLIA FIELD

A structure map of the Petrolia oil and gasfield, made by E. W. Shaw and H. M. Robinson, was published by the Geological Survey in 1916 (Bull. 629). This map shows the surface of the main gas sand by means of contours at 20-foot intervals, which were determined chiefly from well records.

The structure is an irregular shaped dome, with a closure of about 20 feet. On the east side there is a dip of 80 feet in rather less than 2 miles. On the north side, the oil sand dips 80 feet in about one mile. To southwestward there is a dip of 60 feet in 2 miles.

Most of the productive ground was irregularly distributed on the top, and just west of the top, of the dome. An elliptical area, 3 or 4 miles across, includes nearly all the wells.

The surface rocks are lenticular red shale; soft, cross-bedded sandstone, and some blue-gray shale. They belong to the Wichita formation of the Permian.

This field has been the principal gasfield of north Texas, but it is now in its decline. The gas came from sands at 1,500,–1750 feet, and some of the early wells had a capacity of 10 million cubic feet. In 1909, when the gas was piped to Forth Worth, the gas pressure was as high as 740 lbs., but at the end of 1916 it was no more than 157 lbs.

Some 50,000 million cubic feet of gas has been marketed from this field, and probably altogether, the total amount which has come out of the ground is near 70,000 million cubic feet.

The oil has been obtained partly from the deep sands, at 1,500–1,750 feet and partly from shallow sands at about 300 feet. The shallow wells are only small producers, but some of the deeper wells have given a good flow of oil.

The shallow oil sands are in the red Permian strata, but the deeper oil and gas sands belong to the Cisco formation of the Pennsylvanian.

The daily output (Sept., 1919) is 420 barrels; and the total oil produced up to the end of 1919 was about 3 million barrels.

CHAPTER XXI

STRUCTURE IN THE STRAW FIELD

A structure map of this field, made by H. M. Robinson and C. W. Hammon, was published in Bulletin 629. This shows a small dome with a closure of 30 feet, covering an area of less than 2 square miles. The outline of the dome is elliptical, with the length about twice the breadth. The major axis has an E. N. E. direction. The general structure of the surrounding country is a monocline, dipping to the northwest at 70 feet per mile. The dome is situated on a broad terrace on this monocline.

The field was opened in 1914, and in that year the wells were not clustered on the top of the dome, but were at the east end of it, and many of them were far from the top.

The productive sands, at first developed, were in the Strawn formation, at 800–1,800 feet depth below the surface. The wells were small producers.

Since that date many wells have been drilled and the output for 1918 was 221,000 barrels. The daily production in September, 1919, was 225 barrels.

A valuable yield of gas also is obtained. The total capacity of the gas wells in 1916 was estimated at 50 million cubic feet a day.

CHAPTER XXII

APPLICABILITY OF THE ANTICLINAL THEORY

Reviewing the foregoing data, we see that a large part of the Mid Continent oilfields has been structurally mapped. In many of the older fields, however, the structure has not been determined. But, of all the oilfields which have been fully studied, the large majority occur on anticlines and domes—a smaller number are situated on terraces, and a few have resulted probably from lens-shaped deposits or other conditions more obscure.

Among the fields which have been discussed in the previous chapters, almost all are on domes and anticlines. Mention has been made of the following.—

Fields on Domes and Anticlines

which have been discussed above.

Augusta.
Augusta-Gordon.
Billings.
Blackwell.
Boynton.
Cushing, Dropright Dome.
Cushing, Drumright Dome.
Cushing, Mount Pleasant Dome.
Cushing, Shamrock Dome.
Duncan.
Eldorado.
Fort Smith.
Garber.
Healdton.
Lawton.
Loco.
Mervine.
Osage—some 30 fields, mostly small.
Petrolia.
Ponca.
Poteau.
Quinton-Kinta.
Strawn.

Many other fields are known to be on similar structures, though the struc- re maps have not been published.

Other Fields on Domes and Anticlines

*according to various authorities.**

Bald Hill.
Beaumont.
Bigheart.
Boston Pool.
Cole Pool.
Checotah.
Dexter.
Eaton.
Fox.
Hominy.
Ingalls.
McMann Gas Pool.
Morrison.
Muskogee.
Paola.
Robinson Pool.
Stone Bluff.
Vera.
Virgil.
Wagoner.
Wainwright.
Wheeler.
Winfield.
Yale-Quay.
Some 10 fields in North Central Texas.

Fields Stated * to be on Terraces

Bixby.
Catoosa.
Dawson.
Glen (?).
Osage, 3 fields.
Tulsa.
Jenks.
Jennings.
Kellyville.
Morris.
Mounds.
New York Pool.
Owasso.
Pumpkin Center.
Ripley.
Tiger Flats.

Fields Stated * to be Due to Lens Condition

Avant.
Coweta.
Misener.
Wigton.

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* "Evidence of Oklahoma Oilfields on Anticlinal Theory," by Hager. Trans. Am. Inst. Min. Eng., 1917. Also various bulletins. Structure maps of numerous other fields have been made which are not available for production.

PART VIII

CHARACTER OF THE OIL

CHAPTER I

GENERAL CHARACTER OF MID CONTINENT OIL

There is considerable variety among the oils of the Mid Continent Fields, but in general, they are of light gravity, and have rather a high naphtha content. The base is mixed, but consists mainly of paraffin. The percentage of sulphur is very small.

There is variation, not only from field to field, but also from sand to sand, and from well to well. Even from the same well, samples taken at intervals are slightly different.

Probably the differences in character of the oils in the Mid Continent Fields, depend on several factors—perhaps partly on differences in the original matter from which they were produced, but more especially upon differences in their subsequent history,—the different temperatures and pressures to which they have been subjected, and to the different filtrations and diffusions which they have undergone.

The oil consists chiefly of hydrocarbons of the Paraffin Series, together with some 10–40% of hydrocarbons belonging to the unsaturated series.

In the base, paraffin predominates over the asphalt, and both are present only in small quantity.

Owing to the smallness of its amount, the sulphur, in most cases, has not been determined. In a close investigation of some 20 samples of Kansas petroleums, the percentage of sulphur ranged from .10 to .42.

The oil is heavier than that of the Applachian Field, but much lighter than the oil of the Gulf Coast or California.

Appalachian Oil Region............	.80
Mid Continent Oil Region..........	.85
Illinois Oil Region.................	.86
Gulf Coast Oil Region.............	.92
California Oil Region..............	.96

The range of the specific gravities according to published* analyses, is shown in the columns below.

Regarding the samples of oils listed in these tables, it appears that:—

(1) The specific gravity values do not follow any particular geographical distribution.

(2) The oil in the Permian Red Beds is heavier than in the Marine Permian, the Pennsylvanian and the Mississippian.

Oil in Permian Red Rocks,	sp. gr.	.85–.92
Oil in Marine Permian, Pennsylvanian and Mississippian,	sp. gr.	.78–.89

(3) The specific gravity of the oil bears some relation to depth. For the oil in the Marine Permian, Pennsylvanian and Mississippian:

Depth,	0–1,000,	sp. gr.	.84–.89
Depth,	1,000–2,000,	sp. gr.	.79–.88
Depth,	2,000–3,000,	sp. gr.	.78–.86

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* Chiefly from U. S. Geol. Surv. Reports, by D. T. Day and others, and from Kansas State Geological Survey Reports.

CHAPTER II

SPECIFIC GRAVITY OF THE OIL

The following table shows the specific gravities of many specimens of oil, from many of the Mid Continent Fields.

These figures do not necessarily represent the average values for each field—but they apply to the particular samples which have been analyzed and whose analyses were available.

Most of them are taken from analyses by the Bureau of Mines, published by the U. S. Geological Survey; and from analyses by the Kansas University, published by the Kansas Geological Survey.

For those fields from which more than one analysis is available the range of values is indicated.

KANSAS FIELDS

	Field	*County*	*Depth of wells*	*Sp. gr. of oil*	*Gravity Beaume*	*Gasoline, per cent*
17	Winfield	Cowley	3,353	.8271	39.2	20.8
15	Eldorado	Butler	2,400 - 2,650	.8190 - .8496	40.9 - 34.7	15.3 - 18.8
16	Augusta	Butler	2,448	.8270	39.2	23.9
4	Humboldt	Allen	850	.8850 - .8895	28.2 - 27.4	3. - 3.5
5	Chanute	Allen	700 - 737	.8647 - .8706	31.9 - 30.8	3.0 - 6.0
3	Moran	Allen	535 - 735	.8712 - .8799	30.7 - 29.1	7.5 - 10.
14	Peru	Chautauqua	1,070 - 1,100	.8454 - .8557	35.6 - 33.6	7. - 13.
13	Longton	Elk	585	.8637	32.1	12.
2	Rantoul	Franklin	350	.8557 - .8750	33.6 - 30.0	1. - 11.5
1	Paola	Miami	360	.8511	34.5	10.
8	Coffeyville	Montgomery	600 - 625	.8717 - .8822	30.6 - 28.7	6.
10	Wayside	Montgomery	800	.8696 - .8838	31. - 28.4	5. - 9.5
11	Bolton	Montgomery	1,180	.8424	36.2	14.7
6	Erie	Neosho	520	.8658	31.7	3.0
7	Neodesha	Wilson	800 - 820	.8368 - 8373	37.3 - 37.2	16. - 17.
12	Caney	Montgomery	1,000 - 1,200	.8601	32.8	9.0
9	Independence	Montgomery	450 - 600	.8649	31.9	11.2

OKLAHOMA FIELDS

	Field	*County*	*Depth of wells*	*Sp. gr. of oil*	*Gravity, Beaume*	*Gasoline, per cent*
9	Avant	Osage	1,250 - 1,500	.8617	32.49	
10	Big Heart	Osage		.8547	35.58	
36	Checotah	McIntosh		.8610	32.60	
6	Collinsville-Claremore	Tulsa	1,000 - 1,200	.8585	33.10	
25	Cushing—mixed	Creek	1,350 - 2,800	.8190	40.94	25.
28	Cushing-Layton Sand	Creek	1,350 - 1,550	.8187	41.	
27	Cushing-Wheeler Sand	Creek	2,100 - 2,400	.8284 - .8333	39–38	
26	Cushing Bartlesville S.	Creek	2,400 - 2,800	.8211	40.5	
7	Flat Rock	Tulsa		.8635	32.14	
35	Henryetta	Okmulgee	1,200 - 1,500	.8720	30.55	
37	Madill	Marshall		.7887	47.5	25–30
1	Nowata	Nowata	550 - 750	.8525	34.22	15–16
11	Pawhuska	Osage		.8710	30.73	
8	Red Fork	Tulsa	601 - 1,240	.8323 - .8413	38.2 - 37.3	8–15
23	Skitaook	Creek	1,408 - 1,466	.8328 - .8480	37.1 - 35.1	6–11
24	Glen	Creek	1,500 - 1,553	.8333 - .8459	38. - 35.5	7.5–11.5
22	Mounds	Creek	2,340	.8631	32.2	0
33	Morris	Okmulgee	1,600	.8383 - .8403	37. - 36.6	10. –13.
34	Bald Hill	Okmulgee	1,680 - 1,703	.8531 - .8578	34.1 - 33.2	1.5 - 5.4

OKLAHOMA FIELDS (*Continued*)

	Field	*County*	*Depth of wells*	*Sp. gr. of oil*	*Gravity, Beaume*	*Gasoline, per cent*
19	Muskogee—new	Muskogee	1,473 - 1,735	.8264 - .8358	39.4 - 37.5	3.5 - 12.0
18	Muskogee—old	Muskogee	1,000	.8216 - .8328	40.4 - 38.1	0.0 - 4.0
36	Wewoka	Seminole	1,625	.8844	28.3	1.5
40	Gotebo	Kiowa	365 - 443	.8480 - .8552	35.1 - 33.7	2.0 - 3.5
29	Cleveland	Pawnee	1,157 - 1,800	.8383 - .8669	36.9 - 31.5	0.0 - 15.5
12	Bartlesville	Osage	1,480-1,500	.8505 - .8547	34.6 - 33.8	3.0 - 3.5
4	Dewey	Washington	500 - 1,200	.8605 - .8772	32.7 - 29.6	1.0 - 9.5
5	Webber	Washington	1,200 - 1,300	.8368 - .8547	37.3 - 33.8	6.0 - 13.0
20	Alluwe	Roger	4 00	.8413	36.4	10.0 - 15.0
21	Chelsea	Roger	5 00	.8511	34.5	6.0 - 13.5
3	Childers	Nowata	735 - 750	.8439 - .8449	35.9 - 35.7	11.0 - 14.0
2	Delaware	Nowata	812 - 830	.8424 - .8493	36.2 - 34.8	9.0 - 16.5
30	Ponca	Kay	1,550	.7910 - .8140	47.0 - 42.0	22.0
39	Wheeler	Carter	860 - 1,000	.9150 - .9211	23.0 - 22.0	
38	Healdton	Carter	900 - 1,100	.854 - .879	34.0 - 29.0	7.0
32	Garber	Garfield	2,100 - 2,200	.7778 - .8333	50.0 - 38.0	
31	Blackwell	Kay	1,800 - 3,400	.8105 - .8383	42.7 - 37.0	18.0 - 40.0

NORTH TEXAS FIELDS

	Field	*County*	*Depth of wells*	*Sp. gr. of oil*	*Gravity, Beaume*	*Gasoline, per cent*
	Ranger	Eastland	3,050 - 3,600	.8333	38	19
	Moran	Shackleford	2,500	.8485	35	
	Burkburnett	Wichita	1,700	.8333	38	
	Electra	Wichita	870 - 1,910	.813 - .845	42.5 - 36.1	20 - 28.5
	Petrolia	Clay	260 - 720	.820 - .861	40.8 - 32.8	18 - 25

CHAPTER III

DIFFERENCES IN THE OILS OF DIFFERENT SANDS

Not only does the oil vary considerably in character, from field to field, but even in the same field there usually are appreciable differences between the oils found in the different sands.

This is well illustrated by the following analyses from the Cleveland pool.

OIL IN THE CLEVELAND FIELD

	Sp. gr.	*Distillate, 0°–150°*	*Distillate, 150°–300°*	*Residuum*	*Paraffin*	*Asphalt*
Taylor sand.....	.8363	10.0	38.5	51.1	5.7	0.0
Oswego sand....	.8192	6.0	39.5	50.5	4.2	0.0
Skinner sand....	.8192	9.0	45.0	44.2	6.1	0.0
Peru sand......	.8197	8.0	43.0	47.5	4.2	0.0
Bartlesville sand.	.8226	4.0	48.0	47.8	7.6	0.0

In the Cushing field there is a considerable difference in the oils of the three main sands,—that in the middle sand being heaviest and yielding the least gasoline.

There is also appreciable variation in the same sand, from place to place.

The following figures have been quoted for representative samples a few years ago:

Layton Sand.............	Sp. gr.	.8069
Wheeler Sand............	Sp. gr.	.8178
Bartlesville Sand.........	Sp. gr.	.7913

Serial No. of Sample
50
50
54
54
517
50
49
53
48
47
48
48
53
51
51
49

Serial No. of Sample	OILFIELD	Depth of well	Gravity	
			Specific gravity	Degrees Beaume
378	Paola (C. J. Hafey)	360	.8511	34
374	Rantoul (Springer Lease)	350	.8557	33
364	Moran (Smith Lease)	735	.8799	29
356	Humboldt (Fussman Lease)	850	.8822	28
359	Chanute (Beach Lease)	751	.8647	31
387	Erie (Barger Lease)	520	.8658	31
390	Neodesha (T. Johnson Lease)	820	.8368	37
380	Coffeyville (M. Davis Lease)	625	.8717	30
381	Wayside (J. Hall Lease)	800	.8696	31
383	Bolton (G. L. Bank Lease)	1,180	.8424	36
372	Longton (Allen Co. Inv. Co.)	585	.8637	32
370	Peru (Interstate Lease)	1,100	.8454	35
	Eldorado (Sec. 31, T 25, R5)	2,400	.8190	40
	Augusta (Sec. 21, T.27, R4)	2,448	.8270	39
	Winfield (Sec. 6, T.31, R4)	3,353	.8271	39

ILS (According to Dr. T. Day, U. S. Geol. Surv.)

	DISTILLATION BY ENGLER'S METHOD						UNSAT. HYDROCARBONS			
	TO 150° C.		150°–300°		RESIDUUM					
	Percentage by vol.	*Specific gravity*	*Percentage by vol.*	*Specific gravity*	*Percentage by vol.*	*Specific gravity*	*In crude per cent*	*In fraction 150°–300°*	*Paraffin, per cent*	*Asphalt, per cent*
5	10.0	.7202	33.0	.7964	55.8	.9223	19.6	8	7.44	2.94
6	11.5	.7116	29.5	.7950	54.9	.9272	34.0		3.45	2.29
.1	10.0	.7105	25.5	.8125	64.5	.9180	29.2		3.48	1.66
.7	5.0	.7460	26.5	.8205	67.4	.9272	29.6		2.10	1.03
.9	5.0	.7350	36.0	.7993	57.8	.9223	24.0	1	4.25	1.23
.7	3.0		35.0	.7960	61.8	.9162	23.6	2	1.22	.88
3	16.0	.7158	36.0	.7925	47.7	.9091	20.0		3.40	0.08
6	6.0	.7289	33.0	.8030	58.3	.9241	24.4			
0	9.5	.7100	28.0	.8080	59.9	.9396	35.6		4.66	0.61
2	14.7	.7273	31.0	.8095	49.2	.9365	20.0			
1	12.0	.7202	27.5	.7920	59.3	.9229	29.6	5	7.19	0.89
6	11.0	.7218	30.0	.7988	55.3	.9162	12.4	6	4.54	0.42
9	17.5	.7148	39.7	(?)	45.4		14.0	(?)	1.54	(?)
2	23.9	.7249	41.8	(?)	37.1		12.0	(?)	1.61	(?)
2	20.8	.7151	40.9	(?)	41.3		8.0	(?)	1.67	(?)

CHAPTER IV

ANALYSES OF OIL FROM THE FIELDS

Detailed analyses of many of the Mid Continent oils, which have been made by the Bureau of Mines, were published by the Geological Survey ("Petroleum in 1913," by D. T. Day). They include 40 Kansas oils and 77 Oklahoma oils.

Also, the oils of Kansas have been investigated in detail by the Kansas University, and the results have been set forth in the bulletins of the State Geological Survey (see Bulletin No. 3 by R. C. Moore and W. P. Haynes).

Representative examples have been selected from the Geological Survey analyses and from later work at Kansas University. These are shown in tables below.

The maximum and minimum percentages occurring in these analyses are summarized in the brief table which follows:

RANGE OF PERCENTAGES AND VALUES, IN THE ANALYSES OF MID CONTINENT OILS, QUOTED IN THE FOLLOWING PAGES

	Kansas	*Oklahoma*
Specific gravity	.8190–.8895	.8192–.8844
Beaume degrees	40.9–27.4	40.9–28.3
Viscosity	1.31–6.74	1.2–6.6
Color	Green–Black	Green–Black
Gasoline, per cent (0°–150°)	1.0–23.9	1.0–16.5
Kerosene, per cent (150°–300°)	25.0–40.5	28.0–48.0
Residue, per cent	44.1–68.9	44.2–67.3
Unsaturated hydrocarbon, per cent	8.0–50	10.0–39.2
Paraffin, per cent	1.21–7.92	1.24–12.45
Asphalt, per cent	.61–3.20	.0–4.01
Sulphur, per cent	.08 (?)–.42 (?)	Very little

PART IX

THE NATURAL GAS

CHAPTER I

PRODUCTION OF GAS

It is an established fact that the world's great gas reservoirs are in the Palaeozoic rocks. Accordingly, it is not surprising that the Mid Continent Oil Region is one of the chief producers of natural gas.

The gas sands are distributed throughout the same range of formations as the oil sands; and the gasfields occur throughout the same extent of territory as the oilfields.

The exploitation of the natural gas has always been a prominent feature of the industry of the Mid Continent Oilfields.

In the early days of the Mid Continent Fields, the gas was sought for rather than the oil; and, in Kansas, up to the end of 1915 (with the exception of the year 1904), the value of the gas exceeded that of the oil. Soon, most of the towns in eastern Kansas were plentifully supplied with gas —but the heavy drain upon these older fields has now partially exhausted them.

In the ensuing development of the Oklahoma fields, likewise, immense stores of gas were tapped. At first, the demand in Oklahoma was not great, and large quantities of gas were piped into Kansas; but there is now much more gas used in Oklahoma than in Kansas.

In north Texas, the first important supply of gas was that of the Petrolia field, which was piped to Fort Worth in 1909. A considerable quantity of gas is now being found in the new oilfields of the north central part of the State, and is more than making up for the decline of the almost exhausted Petrolia field. The amount of gas used in north Texas is now nearly as great as in Kansas.

In Arkansas, also, a useful quantity of gas has been developed in the past few years.

QUANTITY OF GAS PRODUCED

During the rapid exploitation of new oilfields, there often was no market at hand for such great volumes of gas as were encountered, and much gas has been allowed to flow to waste. Consequently, the figures for gas marketed, are but a very imperfect measure of the actual quantity of gas encountered or liberated.

In Kansas, the quantity of gas produced and marketed in 1917 was 24,439 million cubic feet, with a value over 5½ million dollars. The record quantity was in 1911, amounting to nearly 39,000 million cubic feet.

In Oklahoma, the marketed production for 1917 was 137,384 million cubic feet, with a value of nearly 14 million dollars.

In north Texas, 17,047 million cubic feet of gas was sold in 1917, the value being well over 3 million dollars.

In Arkansas, the volume sold was 5,609 million cubic feet, and the value was ⅓ million dollars.

The output of natural gas, in millions of cubic feet marketed, during the years 1914–1917, is shown in the following table. Statistics for 1918 and 1919 are not yet available.

GAS PRODUCTION, IN MILLIONS OF CUBIC FEET, MARKETED

	Kansas	*Oklahoma*	*Arkansas*	*North Texas*
1914	22,628	78,167	?	13,434
1915	27,046	87,517	992	13,324
1916	31,710	123,519	2,389	15,810
1917	24,439	137,384	5,609	17,047

The number of towns and villages supplied with natural gas, in 1917 was as follows:—

TOWNS AND VILLAGES SUPPLIED, IN 1917

In Kansas	131
In Oklahoma	122
In Arkansas	31
In North Texas	60

The quantity of gas which has been released from the rocks during the past few years in the Mid Continent oil region is immense. From the records, it appears that the total amount which has been marketed, up to the end of 1919, is near 1,700,000 million cubic feet. There is little doubt that the quantity which went to waste exceeded that which was utilized. It was estimated that in Oklahoma alone, 100,000 million cubic feet per annum had been wasted, hence we are probably making a conservative estimate if we say that the total gas released has amounted to not less than 3,000,000 millions of cubic feet—or about 24 cubic miles. Within the rocks, under a pressure of say 500 lbs. per square inch, this gas would have occupied an accommodation of about four-fifths of a cubic mile.

GASFIELDS IN KANSAS

In Kansas there were many gas pools among the early shallow oil pools in the east of the region. One of the oldest and strongest of these was at Iola, near the northern end of the oilfields. Here there were many wells, 800–1,000 feet deep, with a daily capacity exceeding 30 million cubic feet.

Around Independence there were a number of conspicuous gas pools, the wells having capacity up to 37 million cubic feet. In 1905, as much as 700 million cubic feet of gas was "on tap" in Independence.

In the Chanute-Humboldt field, the wells were of 30 million cubic feet capacity.

Later, valuable gasfields were found west of the older oilfields, at Augusta, Arkansas City and other places.

Recently a great gasfield has been opened around Elk City, where it is said that the wells which have now been drilled could, all together, produce a billion cubic feet of gas in a day.

(For further particulars, see Part VI, Chap. 5.)

GASFIELDS IN OKLAHOMA

In Oklahoma, specially important gas pools were developed around Bartlesville, Cleveland, Hogshooter, Morris, etc.; the capacity of the wells being about the same as in eastern Kansas.

The Glen field, and the surrounding oil territory in the east part of Creek County, has produced and is still producing an immense quantity of gas, much of which is now being used for the extraction of "natural gas gasoline."

In the old Glen pool, about 4% of the wells were gas wells, usually with a capacity of 10–40 million cubic feet, and, in some cases, as much as 70 million cubic feet. Many such gas wells were allowed to flow freely into the air for weeks or months—often until they were exhausted.

The Cushing field, from 1913 to 1918, has also been one of the greatest gasfields in the world. In the opening of this oilfield, the gas was found in such quantity that it was a trouble to the drillers.

In 1914, 36 gas wells were drilled, with a combined initial capacity of 608 million cubic feet per day, and a pressure of 800 to 900 pounds; and in 1916, the initial gas capacity of new wells amounted to 1,000 million cubic feet per day.

One of the wells was estimated capable of yielding 100 million cubic feet a day, and was then the largest gas well in the Mid Continent Field.

Year	*No. of new gas wells in Cushing Field*	*Total capacity of new wells*
1914	36	608 million
1915	19	199 "
1916	43	1,000 "
1917	20	157 "

The waste in this field was great. It is calculated that during part of 1913 and 1914, the daily wastage was 500 million cubic feet, and that the total loss must have been 250,000 million cubic feet.

In Kay County the deep drilling has provided some very powerful gas wells during the years (1916–1918). Thus in the Blackwell oilfield, where there has been much drilling down to 3,200 feet and deeper, many gas wells have had capacity 20–35 million cubic feet, and pressure more than 1,000 pounds.

The total initial daily capacities of the wells drilled in Kay County during 1917, amounted to 222 million cubic feet.

In southern Oklahoma, the Healdton oilfield has been a large producer of natural gas since 1914. Most of the gas wells are of large capacity, ranging from 20 to 40 million cubic feet per day, with pressure 500–600 pounds.

Year	*No. of new gas wells in Healdton Field*	*Total capacity of new wells*
1913	3	50 million
1914	9	150 "
1915	14	191 "
1916	5	100 "
1917	14	153 "

During the past two years the Fox gas pool, a few miles north of Healdton, has provided a number of wells of very large capacity.

In southeast Oklahoma, the gasfields are small compared with those already discussed. They are situated on anticlines, in the sharply folded territory north of the Ouachita uplift.

(For further particulars, see Part VI, Chap. 5 and Chap. 6.)

GASFIELDS IN ARKANSAS

In Arkansas also, near the west border of the State, and north of the Ouachita uplift, there are several gasfields, on the rather steep folds which characterize the district.

The principal fields are at Massard Prairie (Fort Smith), drilled chiefly in 1914, and at Kibler, discovered in 1915. From these, the city of Fort Smith and several small towns are supplied.

The wells in the region have had capacities up to 25 million cubic feet, and pressure 250–300 pounds.

(For further particulars, see Part VI, Chap. 5, Section D.)

GASFIELDS IN NORTH TEXAS

In north Texas the Petrolia field yielded a valuable supply of gas, which in 1909 was piped to the cities of Dallas, Fort Worth, etc.

The wells had a capacity of 10–40 million cubic feet, and a pressure of over 700 pounds.

From 1909 to 1915, about 37,000 million cubic feet of gas was supplied from this field.

The new fields in north-central Texas, which were opened during 1918, are now producing a valuable amount of gas.

In the foregoing remarks, mention has been made of only a few of the important fields.

Many other gasfields, large and small, and many other rich gas-areas among the oilfields, occur throughout the Mid Continent Fields. They are far too numerous to be separately discussed in this chapter, and a number of them already have come under mention in the preceding pages. (Parts III, VI, VII.)

CHAPTER II

RELATION BETWEEN GAS POOLS AND OIL POOLS

Gas Pool Adjacent to Oil Pool in Same Sand

In most of the fields the principal oil sand is also an important gas reservoir—and we have a pool of gas and a pool of oil, side by side in the same rock. The greater part of the Mid Continent gas production is from such sands.

In these cases, generally, the gas pool tends to occupy the highest part of the anticline, or the upper edge of the terrace; but this arrangement is not adhered to very exactly, and often the gas pool extends farther down one side of the fold than the other.

Such for example, is the case in the Cushing field, where a great yield of gas was obtained from the Layton Sand, and especially the Wheeler Sand, on the high parts of the domes, and lower down the flanks of the folds important pools of oil occurred in the same sands.

Sometimes the gas and oil are more irregularly distributed in the sand, and there is no guide as to the whereabouts of the bodies of gas.

Probably these irregularities of distribution are due to irregular bedding in the sand—for a thick sandstone will have many lenticular streaks of different porosity, and these may lead to the isolation of great bubbles of gas in unexpected places.

In the Bartlesville Sand of the Cushing field, such pockets of gas frequently were encountered, giving gas wells with initial capacity of 40 million cubic feet and a high pressure. But, evidently, the gas reservoirs were small and isolated, for the supply, in these cases, usually soon failed.

Gas Pool Over Oil Pool in Same Sand

In some fields, where the oil sand is very thick, a large gas production is taken from the top part of the sand, whilst important oil production is being obtained, at the same spot, from the lower part of the bed.

Throughout the Bartlesville district, where the Bartlesville Sand is 50 feet or more in thickness (lying at a depth of 900–1,200 feet), there were gas pools of this nature, and many gas wells gave as much as 30 million cubic feet per day. It must be observed however, that though a large yield of gas was obtained from the Bartlesville Sand in this way, the greater part of the gas production of these rich fields was from other gas sands beneath the oil sands.

Gas Pool in Sand Under Sand Containing Oil Pool

A considerable proportion of the gas in the older Mid Continent Fields is from sands which are underneath the oil pools.

Throughout the shallow fields of southeast Kansas and northeast Oklahoma, in the districts where the Bartlesville oil sand was so richly productive at 900–1,200 feet, thousands of wells were drilled for gas, a further 100–200 feet, into sands known as the Mississippi, Tucker and Burgess Sands.

In the gas pools of the Bartlesville district, the Independence district, and indeed in the eastern part of the region generally, these gas wells usually have had an initial capacity of about 30 million cubic feet per day, and pressure from 300 to 500 pounds.

This occurrence of strong gas sands so close beneath the oil sands, is one of the interesting features of this field in connection with the origin of oil and gas.

In many instances the gas sand, with a pressure of 300–400 pounds, is separated from the oil sand by only 30–100 feet of shales. In such cases there can, of course, be no communication between the two sands, or else the gas would change places with the oil. This is further shown by the normal behavior of the wells drilled to the oil sand, for were there any connection between the two sands, the gas would blow the oil out of the wells.

If the oil and gas had not originated in the materials immediately above and below the sands, but instead had come up from some mysterious depths, it would be difficult to explain how the oil came to occupy the higher sand whilst the gas was imprisoned in the lower sand.

Gas Pool in Sand Above Sand Containing Oil Pool

In most of the Mid Continent oilfields, valuable gas production has been found also in sands above the oil sands; indeed in the past three years, several important oilfields have been discovered by drilling deeper in fields which previously had been developed only for gas. This applies particularly to the western fields, where the main oil sands lie at a considerable depth, such as the Augusta field in Kansas, and the Blackwell and Ponca fields in Oklahoma.

The Augusta gasfield was drilled in 1913 in a gas sand lying at 1,500 feet. The wells had initial capacity up to 40 million cubic feet, with a pressure of 650 pounds. By the year 1915, however, the pressure had fallen to 400 pounds. During 1915, deeper drilling was tried, and resulted in the discovery, at 2,450 feet, of the highly productive Varner oil sand.

At Ponca, at a depth of 550 feet, there was a gas sand in which some wells had a production of 7 million cubic feet per day. Beneath this, oil and gas sands were found at 975, 1,330, 1,550, 3,300 feet, and finally the important oil production is reached at 3,900 feet.

In the Blackwell field a remarkable succession of gas sands overlies the oil. At first the gas production was found in a sand at 750 feet, the early wells having a capacity of 5 million cubic feet a day.

But deeper drilling, in 1915 and 1916, disclosed a number of prolific gas sands, followed by an oil sand at 3,300 feet in which initial yields of 1,000–2,000 barrels a day were obtained. (More recently important oil production has been found in a sand at 1,800 feet.)

In some of these deep wells, the potential production of gas has exceeded 100 million cubic feet a day. The following is a record of the gas sands in one of the wells:—

Gas sand	*Depth*	*Pressure*	*Estimated daily capacity*
First	692	300	8 million cubic feet
Second	785		1 " " "
Third	940		15 " " "
Fourth	1,170		2 " " "
Fifth	1,350		20 " " "
Sixth	1,900		20 " " "
Seventh	2,600		20 " " "
Eighth	3,200	1,260	30 " " "

In the Yale-Quay field which has been developed in the past three years, the oil lies at great depth, and rich gas sands occur above it.

Depth	*Sand*	*Result*
2,720	Gas only	Some gas production.
2,875	Gas and a little oil	Large gas production—wells with capacity 20 million cu. ft., pressure—1,100 lbs.
3,050	Oil	Some oil production.
3,130	Oil	Large oil production—wells 200–600 bbls.

It is not necessary to quote further instances of the occurrence of productive gas sands above the oil, as such conditions are common throughout the region.

Gas Pool Without Oil Pool

Comparatively few of the Mid Continent Fields contain gas without oil—though in a number of them, gas production was developed before the discovery of the oil.

However, in the one exceptional area where the petroliferous formations have undergone pronounced folding, gas alone is found.

In this strip of sharply folded territory north of the Ouachita uplift, in southeast Oklahoma and western Arkansas, there are a number of gasfields, such as Massard Prairie (Fort Smith), Kibler, Poteau, etc., in which large quantities of gas occur without oil.

The gas is produced from Pennsylvanian deposits, and the fields are situated on sharp anticlinal folds.

The wells have capacities up to 20 million cubic feet per day, or more, and pressure of several hundred pounds; but, although a number of deep test wells have been drilled, no more than traces of oil are found.

CHAPTER III

RELATION OF GAS PRESSURE TO DEPTH

Throughout the region, the gas pressure generally is roughly proportional to depth. It approximates closely to the hydrostatic pressure due to a column of water of that depth, viz., about 43 pounds per 100 feet. This applies not only to the shallow fields in the east, with depths 500–1,200 feet and pressures 200–500 pounds, but it also applies equally to the deeper western fields, with depth 2,000–3,500 feet, and pressure 800–1,500 pounds.

The following are a few examples:—

Field	*Depth in feet*	*Pressure in pounds*	*Initial yield in millions of cubic feet*
Caney, Independence, Chanute, Cherryvale, etc.	400–1,200	150–500	1–40
Iola	840	350	1–30
Neodesha	984	425	1–30
Healdton	1,000	425	20–40
Canary	1,175	440	31
Dewey-Bartlesville	1,280	464	15
Augusta	1,500	650	5–15
Petrolia	1,650–1,700	740	10–40
Cushing	2,200	850	10–50
Yale-Quay	2,875	1,100	20
Blackwell (2 deep wells)	692	300	8
	3 200	1,260	30
	3,400	1,500	12
Poteau	1,500	412	1–5

CHAPTER IV

EXHAUSTION OF GASFIELDS

There is no evidence of replenishment of the gasfields, but, to the contrary, the exhaustion is rapid and almost complete. The exhaustion is most readily expressed by the decline in pressure.

The following instances will illustrate the history of all the exploited gasfields:—

In the large gasfield of South Independence, Kansas, at the beginning of 1905, the pressure was 340 pounds—but in 8 years of active exploitation, it declined to 75 pounds.

The gasfield of West Chanute, Kansas, had an average pressure of 145 pounds about the middle of 1908; but by the end of 1912, the average as determined from 43 wells, was less than 10 pounds.

In the famous Caney gasfield (Kansas), during 1908–1911, the average daily volume of the wells fell from 10.8 million cubic feet to .2 million cubic feet, and the pressure declined from 540 pounds to 150 pounds.

In the Copan gas pool, Oklahoma, during 1909–1911, the pressure fell from 440 pounds to 18 pounds, and the average capacity of the wells from 31½ million cubic feet to 1 million cubic feet.

In the Dewey-Bartlesville field, during the same period, the pressure fell from 464 pounds to 219 pounds, and the average initial capacity from 16 million to 9½ million cubic feet.

In the Hogshooter field, Oklahoma, very heavy consumption of gas was accompanied by an exceptionally rapid decline. At one time, 200 million cubic feet per day was being piped away, and in two years, between October, 1910, and October, 1912, the pressure fell from 575 pounds to about 100 pounds. After two more years, there was no surplus of gas to export from the field.

In the Petrolia gasfield of north Texas, at the opening in 1907, the early wells had a productive capacity of 10–40 million cubic feet a day. The gas was piped away to Fort Worth in 1909, and in the ensuing six years, some 50,000 million feet of gas was released. In this period the pressure fell from 740 pounds to 350 pounds, and by the end of 1916, it had declined to 175 pounds.

CHAPTER V

CHEMICAL CHARACTER OF THE NATURAL GAS

The natural gases of many of the Mid Continent fields have been analyzed by the United States Bureau of Mines—and they have also been the subject of important researches at the University of Kansas.

The composition of the gases varies widely in neighboring fields.

The gas, as usual, consists essentially of the paraffins, Methane and Ethane, accompanied by Nitrogen in smaller varying amounts. Other constituents, present only in very small quantity, are Oxygen, Carbon dioxide, Carbon Monoxide, Olefines, Hydrogen, Helium, Argon, Neon, Xenon, Krypton.

In most of the fields, paraffins make up 95–98 per cent of the gas, but there are many in which Nitrogen is an important constituent, and the paraffins then amount only to 80–90 per cent or 75–80 per cent, and in extreme cases, less than 15 per cent.

The paraffin is mainly Methane (CH_4) and sometimes it is wholly Methane, especially in those gases which have very high percentages of paraffins.

In many ordinary gases, however, the analysis shows a considerable proportion of the next paraffin—Ethane—(C_2H_6), the amount varying from 0 to 12 per cent or more.

The really wet gases (casinghead gas), however, in addition to Methane and Ethane, contain some small amount of Propane, Butane, Pentane and Hexane which are readily condensible to gasoline.

Here, it must be observed that when the analysis of a gas shows Ethane to be present in appreciable quantity, it may be taken for granted that Propane and Butane also are present and possibly some Pentane and Hexane.

The ordinary method of analysis, which consists in burning the paraffins and measuring the volume of Carbon dioxide produced, does not completely solve the problem—because, the identical result could be given by a number of different paraffins—for instance,—2 molecules of Ethane produce the same result as 1 molecule of Methane and 1 of Propane. Hence as we do not know just which paraffins are present, it is customary to express them in the analysis as so much Methane and Ethane. Therefore, in reading an analysis, it must be realized that some of the Ethane in the column should really be split up into Methane and Propane, or Methane and Butane, or Methane and Pentane, etc.

The Nitrogen is present in all specimens analyzed, generally to the extent of from 2–10 per cent, but in a number of fields, especially those in the west, the amount is from 10–16 per cent. In certain places there are gases containing an extraordinary amount of Nitrogen, for instance, Dexter, 82.70 per cent and Eureka, 46.40 per cent, Petrolia, 38.6 per cent.

The rarer elements, Helium, Argon, etc., usually are not present in appreciable quantity except in those gases which are rich in Nitrogen.

In the table of gas analyses quoted below (excluding the gas drawn from the Glen pool under reduced pressure), the percentage of the constituents varies between the following limits:—

Hydrogen	0.	to	0.10
Methane	14.85	to	98.00
Ethane	0.	to	13.90
Nitrogen	0.88	to	82.70
Helium	0.0093	to	1.84
Olefines	0.00	to	0.81
Carbon Dioxide	0.	to	0.93
Carbon Monoxide	0.	to	0.20
Oxygen	0.	to	0.40

SOME ANALYSES OBTAINED BY RESEARCH IN THE UNIVERSITY OF KANSAS, 1905–1907

(Papers by Cady, McFarlane, etc.)

	PARAFFINS		OLEFINE	HYDROGEN	NITROGEN	HELIUM	OXYGEN	CARBON DIOXIDE	CARBON MONOXIDE	*Depth of well in feet*	*Pressure in lbs. per sq. inch*	*Capacity of well in millions of cu. ft. per day*
	Methane CH_4	*Ethane* C_2H_6	C_2H_4	H_2	N_2	He	O_2	CO_2	CO			
Dexter	14.85	.41	.00	trace	82.70	1.84	.20	.0	.00	310	110	6
Eureka	51.80	.00	.00	0	46.40	1.50	.10	.20	.00	375	85	
Elmdale	78.60	7.71	.55	0	12.13	.56	.30	.15	.00	150	45	1
Olathe	84.40	.00	.10	0	15.10	.40	.00	.00	.00	580	184	
Augusta	79.10	7.44	.77	0	12.44	.25	.00	.00	.00	1,420	650	
Chanute	94.70	.00	.00	0	4.96	.24	.10	.00	.00	850	200	
Moran	92.00	.00	.35	0	6.35	.214	.20	.30	.20			
Peru	81.70	7.60	.51	0	9.39	.19	.10	.51	.00			
Iola	94.50	.00	.00	0	5.08	.183	.23	.00	.00	Mains		
Arkansas	81.10	11.95	.10	0	6.39	.159	.20	.10	.00	750	355	5
Blackwell	83.40	10.31	.61	0	5.19	.16	.00	.00	.00	640	185	1
Humboldt	94.00	1.97	.81	0	2.98	.14	.10	.00	.00	Mains		
Erie	90.30	4.26	.30	0	4.45	.13	.22	.33	.00	510	150	
Caney	92.40	.00	.10	0	6.46	.08	.15	.81	.00	1,550	620	
Paola	98.00	.00	.00	0	.88	.0093	.40	.70	.00	Mains		

ANALYSES PUBLISHED BY THE BUREAU OF MINES, ETC.

* Glen pool	49.1	44.1			.7			6.1				
Duncan	91.9	4.1			3.6			.4				
Loco	80.2	11.1			8.7			0.0				
Fort Smith	96.12		.02	.01	2.71		.13	.93	.08	Mains		
Petrolia	48.4	12.8			38.6	.9	.00	.2				
Strawn	79.00	13.90			7.10							

* Drawn from well, under reduced pressure of 20 inches of mercury and used for extraction of gasoline.

CHAPTER VI

HELIUM IN THE NATURAL GAS

An interesting result of the research by Cady and McFarland, was the discovery that Helium is present in natural gas. In Kansas the amount is quite appreciable, ranging from .0093 to 2 per cent, and in general, being present to the extent of a quarter of 1 per cent.

The percentage of Helium is greater in the gases with the higher nitrogen content. The "Iso-Helium lines" when drawn on the map, appear to be parallel to the strike of the formation, the amount of Helium steadily increasing to westward. This, however, may be due to the gases richer in nitrogen occurring in the west.

Until recently the highest content of Helium known in natural gas was 1.84 per cent. This occurred at Dexter (Cowley Co.), in a "wind gas" which was struck at 400–500 feet. This gas consisted mainly of nitrogen (82.7 per cent), and being then of no value, was allowed to go to waste.

Recently it has been announced that Helium to the extent of 2 per cent, is present in gas found at 600–1,200 feet, in the Augusta Oilfield (Butler Co.).

Helium is one of the rare elements, and was first discovered by Lockyear in the solar spectrum. Subsequently it was found, by Sir W. Ramsay, on the earth in minute quantity, given off from certain minerals, probably in connection with radium emanations.

Helium came into public notice lately as a munition of war. It is an inert gas, lighter than every other element except hydrogen. It possesses a great advantage over hydrogen for use in airships and balloons, in that it is not inflammable. Its lifting power is only slightly less.

Compared with hydrogen, its density is 1.98, whilst the density of air is about 14.39. Therefore, its lifting power, compared to that of hydrogen is $\frac{14.39 - 1.98}{14.39 - 1.} = 92.7\%$.

Up to the end of 1917, in all the world, probably no more than 100 cubic feet of Helium had ever been separated—and the cost of it has been figured at $1,700 per cubic foot.

In 1917, the preparation of Helium for use in war air-craft, was undertaken at the instigation of the United States Bureau of Mines, and a commission from the British Admiralty. Sums amounting to $700,000 were voted by the United States Aircrafts Board for the furtherance of the scheme. Under the directions and advice of Dr. G. A. Burrell, Dr. F. G. Cottrell, Mr. F. E. Norton, Mr. V. H. Manning, Dr. Moore, Professor Cady and Mr. D. F. McFarland and others, a plant was constructed to separate Helium from natural gas on a commercial scale.

The Kansas gases, rich in Helium, were no longer obtainable in quantity. The best available source known was the gas from Petrolia, which contained .9 per cent of Helium, and which was being delivered through a pipe line to Fort Worth at the rate of 20 million cubic feet a day.

[Due to the heavy consumption, it was soon found necessary to turn other gas less rich in Helium into the pipe-line, which lowered the percentage to .4 or .5.]

The separation of Helium from the other constituents of natural gas is difficult, even in the laboratory—because, after the hydrocarbons and other active gases have been removed by combustion or other chemical reactions, we are left with the Nitrogen, Helium, and the traces of the other inert gases, Argon, Neon, Xenon, Krypton, which refuse to enter into chemical reaction.

The only satisfactory method of separating out the Helium from these is by liquefaction, for Helium is much more difficult to liquefy than the other gases; in fact, it never has been liquified, as its critical temperature (— 264° C) is only a few degrees above the absolute zero. Thus, under pressure and low temperature, the nitrogen is liquified, but the Helium remains as a gas.

Liquefaction processes, therefore, were adopted, and at Forth Worth, a Linde plant and a Claude plant were constructed, each to have an output of 7,000 cubic feet of Helium per day.

The Linde plant, which cost about $300,000 started operating March 6, 1918. By September, it was able to maintain an average daily output of 5,000 cubic feet of Helium of 70 per cent purity; and by a second treatment, this product was brought to 93 per cent purity.

The Claude plant, which cost about $150,000 was started later, and has not achieved so much results.

In November, 1918, at the signing of the Armistice, the first consignment, consisting of 147,000 cubic feet of 93% Helium, was on the dock awaiting shipment to Europe.

The army and navy have now undertaken a larger programme and have allotted 5 million dollars for the erection of additional units of the Linde plant, and for laying new pipelines. A plant is now under construction capable of producing at least 50,000 cubic feet of Helium a day—at a cost of not more than 10 cents per cubic foot.

PART X

PRODUCTION OF GASOLINE FROM NATURAL GAS

CHAPTER I

THE GASOLINE IN GAS

An important industry has grown up in the past 6 years, in producing a light oil from natural gas.

During 1917, more than 100,000 million cubic feet of gas were treated in the Mid Continent Fields—and the output of this "Casinghead" gasoline was near 3 million barrels (which was then half of the world's production by this method).

(Statistics for 1918 and 1919 are not yet published.)

	Kansas	*Oklahoma*	*N. Texas*	*Total (Barrels)*
1914	1,000	411,360	......	412,360
1915	2,000 (?)	753,952	......	755,952
1916	5,119	1,151,419	30,780	1,187,308
1917	27,976	2,741,034	160,000	2,929,010

Both the compression process and the absorption process are in use. Some 245 plants were in operation in 1917, of which about 35 were for absorption. During 1918 and 1919 there was a great expansion of the industry, but statistics are not yet available.

The hydrocarbons, of which natural gas is essentially composed, are almost wholly those of the Paraffin Series—Methane, Ethane, Propane, Butane, Pentane, etc. Other hydrocarbons are present only in such small amounts that they need not be considered in this connection.

Also, the nitrogen, helium, etc., may be dismissed, as they contribute nothing towards the gasoline, but merely figure as dilutants of the parent gas.

The physical properties of the paraffins and their relationships in petroleum and natural gas are set out in the accompanying table.

CHAPTER III

RELATION OF GAS PRESSURE TO DEPTH

Throughout the region, the gas pressure generally is roughly proportional to depth. It approximates closely to the hydrostatic pressure due to a column of water of that depth, viz., about 43 pounds per 100 feet. This applies not only to the shallow fields in the east, with depths 500–1,200 feet and pressures 200–500 pounds, but it also applies equally to the deeper western fields, with depth 2,000–3,500 feet, and pressure 800–1,500 pounds.

The following are a few examples:—

FIELD	*Depth in feet*	*Pressure in pounds*	*Initial yield in millions of cubic feet*
Caney, Independence, Chanute, Cherryvale, etc.	400–1,200	150–500	1–40
Iola	840	350	1–30
Neodesha	984	425	1–30
Healdton	1,000	425	20–40
Canary	1,175	440	31
Dewey-Bartlesville	1.280	464	15
Augusta	1,500	650	5–15
Petrolia	1,650–1,700	740	10–40
Cushing	2,200	850	10–50
Yale-Quay	2,875	1,100	20
Blackwell (2 deep wells)	692	300	8
	3 200	1,260	30
	3,400	1,500	12
Poteau	1,500	412	1–5

The natural-gas-gasoline of commerce consists of the paraffins Pentane, Hexane and Heptane—together with some of the lower member Butane, and some of the higher member Octane. There is also a small amount of the gas, Propane, held in solution.

Butane	C_4H_{10}
Pentane	C_5H_{12}
Hexane	C_6H_{14}
Heptane	C_7H_{16}
Octane	C_8H_{18}

Thus this liquid is more volatile and inflammable than the ordinary gasoline produced from crude oil, which is composed principally of Heptane, Octane and Nonane, together with a less amount of Pentane and Hexane and some Decane.

The natural gas product, therefore, is troublesome to handle and is too dangerous for common use. But by mixing it with the heaviest of the gasoline distillates obtained from crude oil, which consist mostly of Octane, Nonane and Decane, a liquid is produced having the same specific gravity as ordinary commercial gasoline. Chemically it differs from them, in that it is composed of more equal proportions of all the paraffins from Pentane to Decane, instead of a preponderance of Heptane, Octane and Nonane.

DRY GAS AND WET GAS

Natural gas which holds a conspicuous amount of the liquid paraffins is termed "wet" gas, in contrast to the ordinary "dry" natural gas.

In dry gas, the paraffin is wholly, or almost wholly, Methane; and as the Methane can only be kept liquid at a very low temperature, there is no gasoline to be extracted from such a gas.

But in wet gas, the analysis shows a high percentage of Ethane—which as previously explained (Part IX, Chap. V), is really an expression of the presence also of Propane, Butane, Hexane, Heptane and Octane: and these constitute "Natural-gas-gasoline," or "Casinghead" gasoline.

"CASINGHEAD GASOLINE"—"NATURAL GAS GASOLINE"

The principal source of natural-gas-gasoline is not the gas of the large gas pools, which occurs under considerable pressure—but is Casinghead gas, or gas closely associated with oil, which is drawn from the oil wells in the large oilfields. Usually this gas occurs at low pressure, and in many fields it is pumped from the wells under partial vacuum—after the well has ceased to give any flow of oil.

This Casinghead gas consists largely of gas which was dissolved in the oil, and of vapor drawn from the oil, and from the oil sand. The close relationship between the natural-gas-gasoline and the crude oil, is illustrated by the following instance:

In the Bird Creek pool, the oil from the Bartlesville and Tucker sands is of low gravity (sp. gr. .85), and on distillation it yields only 1 to 2 per cent of low-grade gasoline. Accordingly, the natural gas in these sands yields no gasoline. But, in the Burgess sand, below, the oil is much lighter,—and the natural gas, in this sand, yields 4 gallons of gasoline per 1,000 cubic feet.

It might be thought that this suction of wet gas from the oil wells would result in an equivalent loss of gasoline from the crude oil. But it is common experience that much more gasoline is obtained from the gas than is lost by the oil.

For instance, the following observation in the Glen field:—

A 5-day test, Jan 9–13, was made over 6 leases in 1911, two years before the pool was put under vacuum,—and it was found that the oil had sp. gr. .8393. On the same leases, 7 years later (Jan. 23, 1918),—the field being under a vacuum of 18–20 inches of mercury,—the average sp. gr. of the crude oil was .8419; and at the same time, for every 4 barrels of this crude oil, there was also a production of 1 barrel of Casinghead gasoline, of sp. gr. .6363-.6222.

The following is an analysis of Casinghead gas drawn from wells in the Glen field under reduced pressure of 20 inches of mercury:—

Methane	49.1
*Ethane	44.1
Nitrogen	.7
Carbon dioxide	6.1

After the compression process had been applied, and gasoline had been extracted, the composition of the gas was found to be:—

Methane	60.7
*Ethane	35.8
Nitrogen	.6
Carbon dioxide	2.9

The density of the gas (compared with air), was:—

Before the operation	.83
After the operation	.76

---

* This Ethane content, as previously explained, includes Propane, Butane, Pentane, Hexane, etc.

pockets of gas frequently were encountered, giving gas wells with initial capacity of 40 million cubic feet and a high pressure. But, evidently, the gas reservoirs were small and isolated, for the supply, in these cases, usually soon failed.

Gas Pool Over Oil Pool in Same Sand

In some fields, where the oil sand is very thick, a large gas production is taken from the top part of the sand, whilst important oil production is being obtained, at the same spot, from the lower part of the bed.

Throughout the Bartlesville district, where the Bartlesville Sand is 50 feet or more in thickness (lying at a depth of 900–1,200 feet), there were gas pools of this nature, and many gas wells gave as much as 30 million cubic feet per day. It must be observed however, that though a large yield of gas was obtained from the Bartlesville Sand in this way, the greater part of the gas production of these rich fields was from other gas sands beneath the oil sands.

Gas Pool in Sand Under Sand Containing Oil Pool

A considerable proportion of the gas in the older Mid Continent Fields is from sands which are underneath the oil pools.

Throughout the shallow fields of southeast Kansas and northeast Oklahoma, in the districts where the Bartlesville oil sand was so richly productive at 900–1,200 feet, thousands of wells were drilled for gas, a further 100–200 feet, into sands known as the Mississippi, Tucker and Burgess Sands.

In the gas pools of the Bartlesville district, the Independence district, and indeed in the eastern part of the region generally, these gas wells usually have had an initial capacity of about 30 million cubic feet per day, and pressure from 300 to 500 pounds.

This occurrence of strong gas sands so close beneath the oil sands, is one of the interesting features of this field in connection with the origin of oil and gas.

In many instances the gas sand, with a pressure of 300–400 pounds, is separated from the oil sand by only 30–100 feet of shales. In such cases there can, of course, be no communication between the two sands, or else the gas would change places with the oil. This is further shown by the normal behavior of the wells drilled to the oil sand, for were there any connection between the two sands, the gas would blow the oil out of the wells.

If the oil and gas had not originated in the materials immediately above and below the sands, but instead had come up from some mysterious depths, it would be difficult to explain how the oil came to occupy the higher sand whilst the gas was imprisoned in the lower sand.

Gas Pool in Sand Above Sand Containing Oil Pool

In most of the Mid Continent oilfields, valuable gas production has been found also in sands above the oil sands; indeed in the past three years, several important oilfields have been discovered by drilling deeper in fields which previously had been developed only for gas. This applies particularly to the western fields, where the main oil sands lie at a considerable depth, such as the Augusta field in Kansas, and the Blackwell and Ponca fields in Oklahoma.

The Augusta gasfield was drilled in 1913 in a gas sand lying at 1,500 feet. The wells had initial capacity up to 40 million cubic feet, with a pressure of 650 pounds. By the year 1915, however, the pressure had fallen to 400 pounds. During 1915, deeper drilling was tried, and resulted in the cording to the nature of the gas, and according to the details of the process. In some cases it is as high as 12 or 13 gallons per thousand cubic feet of gas, and in others, as little as 1 gallon or less, per thousand cubic feet, is being obtained profitably.

The average during 1917 was about 2½ gallons per thousand cubic feet.

During recent years, the yield has been as follows—:

1911	2.68	gallons	per	thousand	cubic	feet
1912	2.25	"	"	"	"	"
1913	3.00	"	"	"	"	"
1914	3.01	"	"	"	"	"
1915	3.60	"	"	"	"	"
1916	3.27	"	"	"	"	"
1917	2.987	"	"	"	"	"

The richest source of this Casinghead gasoline in the United States is the low pressure gas of the Glen pool, where the average yield is 3–4 gallons per thousand cubic feet, and in some cases as much as 8 gallons. (The largest source of Casinghead gasoline from high pressure gas is the Cushing field.)

The following data are from some of the large plants in the Mid Continent fields. (Bureau of Mines.)

FIELD	*Plant No.*	*Gas per day in millions cu. feet*	*Barrels of gasoline produced per day*	*Yield, gallons per 1,000 cu. feet*	*Sp. gr. of gasoline*
Glen.............	32	3.0	539	7.40	.654
“	33	1.8	214	5.00	.660
“	36	2.0	55	1.10	.673
“	34	0.75	125	7.00	.660
“	48	1.2	57	2.00	
Morris...........	44	0.5	44	3.60	
“	58	2.0	71	1.50	
Cushing..........	49	2.0	67	1.40	
Cleveland.........	50	1.2	48	1.67	
Muskogee........	51	0.25	22	3.70	
Nowata..........	54	2.25	238	4.00	
“	55	1.25	38	1.30	
“	60	1.00	45	1.90	
Beggs............	45	0.35	17	2.10	

Production of Casinghead gasoline in the Mid Continent Field, by the compression process during 1917, is estimated;—

	Number of plants	*Millions of cu. ft. of gas treated*	*Gasoline produced, (barrels)*	*Gallons per 1,000 cu. ft.*
Kansas..............	1	41	2,460	2.5
Oklahoma...........	207	36,399	2,588,766	2.987
North Texas.........	8	2,800 (?)	100,000 (?)	1.5 (?)

Thus, the production by the compression process in the Mid Continent Oilfields during 1917, was over $2^2/_3$ million barrels, the average yield being near 3 gallons of gasoline per thousand cubic feet.

CHAPTER III

PRODUCTION BY THE ABSORPTION PROCESS

The Absorption Process, which has come into use in the past four years, is applicable to the ordinary kinds of natural gas, which occur in great abundance throughout the region. It is being installed in many fields, and is likely to become more important than the Compression Process.

At present the two processes are used for two different types of gas.

Ordinary natural gas, containing less than 1 gallon of gasoline per thousand feet, was too "lean" to be profitable under the Compression Process; and previous to 1916, only the exceptionally "wet" gas, drawn fron oil wells, was generally utilized as a source of gasoline.

But the Absorption Process is giving profitable results with almost any gas in the region—"lean" gases containing only ½ a gallon of gasoline per thousand cubic feet, and even "dry" gases which yield no more than a tenth of a gallon per thousand cubic feet.

The process consists in passing the gas through an oil heavier than gasoline, which absorbs the gasoline from this gas by solution. The gasoline is then recovered by fractional distillation. Another method is to pass the gas through a very light refined oil until sufficient gasoline is absorbed to bring the solution to the density of commercial gasoline.

The operation is not expensive, and the gasoline obtained is a valuable by-product at pump stations on pipe-lines handling large quantities of gas.

Production of gasoline from natural gas in the Mid Continent fields, by the Absorption Process, in 1917, is estimated:—

	Number of plants	*Gas treated, millions of cubic feet*	*Gasoline produced, barrels*	*Gallons per 1,000 cubic feet*
Kansas	5	9,274	25,500	.116
Oklahoma	27	48,320	152,250	.132
North Texas	3	10,000 (?)	70,900 (?)	.298 (?)

(The figures for Texas include some gasoline produced by compression.)

PART XI

SALINITY OF OILFIELD WATERS

The relation between the salinity of the waters, and the oil, is a subject which calls for more attention.

In all of the oilfields, the oil in the oil-sands rests upon water. In each oil-pool if we proceed to test the oil-sand in a down-dip direction we at length find a limit, beyond which water occupies the sand. In the following pages this water will be referred to as "under-water." (By some writers the term "bottom water" has been used, but this term has been applied also differently.)

It is generally considered that this "under-water" is a "connate" water belonging to the deposits—that it is in fact some of the original sea in which the sediments were laid down.

In most of the oilfields water is found also in other sands besides the oil-sands—especially in the sands which are above the oil-pool and which do not lie very deep. This water usually is surface-water which has entered into the sandstones at their outcrop. Of course these same "water sands" also may contain oil-pools at other localities further down the dip wherever the structure and other circumstances happen to be favourable. The water which has entered a sand at outcrop will almost invariably occur at a higher elevation than any oil-pool which may elsewhere occupy the sand. This water may conveniently be referred to as "upper-water." (The term "top water" is used by some geologists).

Thus in general an oil-sand carries "under-water" further down the dip, immediately beyond the oil-pool. Also on the opposite side of the oil-pool, at a distance, further up the general dip of the monocline, the same sand carries "upper-water."

The under-waters in a sand have usually had a long and varied history, having suffered many changes and movements to and fro among the beds. The upper-waters also may have penetrated far; and often admixture of the two classes of water has occurred. Thus it is not always possible with certainty to place an underground water definitely in either of these two classes.

So far as the subject has yet been investigated, wherever upper-waters and under-waters are quite distinct, they differ markedly in their chemical contents.

It would be interesting to compare analyses of the upper and under-waters of the same sand,—but unfortunately such data are not available. But in a number of fields analyses have been made of the various waters encountered and thus we can compare the under-water of the oil-sand with the upper-water found in other sands above.

Such studies have been made in some of the Californian, Appalachian, and Mid-Continent fields; and at present the results obtained in these different regions widely differ.

Interesting particulars about the waters in the Eldorado, Augusta, and other of the Mid Continent fields, have recently been published in a paper * by R. O. Neal.

In all the cases that have come to his notice there is the same sharp distinction between the upper-waters and the under-waters.

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* Bulletin of Am. Inst. Mining Engineers, March, 1919.

The upper-waters contain a much greater amount of total solids, and but little or no sulphates. The under-waters contain a much less amount of total solids, but a considerable quantity of sulphates.

In the Augusta and Eldorado fields, some hundreds of water samples were analyzed. It is conclusively shown that the water below the oil, in the main oil sand (Varner Sand, 2,500 feet), differs from the water in the water sands above, in that—

(1) It contains only about one-third as much solids in solution.

(2) It contains a conspicuous quantity of sulphat.

The water in this sand has almost constant composition throughout the oilfield. The waters of the other sands differ among themselves in some degree, but all have the above-mentioned wide difference from the water of the Varner Sand.

This fact is of practical use, for when water is struck at about the depth where oil was hoped for, a chemical test discloses whether or not the oil sand has been reached.

The water in the Varner Sand bears a close resemblance to sea water. This, however, is probably a coincidence, for the chemical contents of the water will have undergone many changes during the long imprisonment of the water in the rocks and the alterations in temperature and pressure which have occurred.

ANALYSES OF WATERS IN THE AUGUSTA AND ELDORADO OILFIELDS

	SEA WATER	WATER IN OIL SAND		UPPER WATER			
	Sea Water	*Varner Oilsand, Augusta Field, Below 2,500 ft. average of 20 samples*	*Varner Oilsand, Eldorado Field 2,450 ft.*	*Water sand, Augusta Field 2,160 ft. w*	*Water sand, Augusta Field 1,280 ft.*	*Water sand, Augusta Field 1,660 ft.*	*Water sand, Eldorado Field 1,500 ft.*
Primary salinity, per cent	78.60	79.18	80.20	80.24	80.92	74.41	81.32
Secondary salinity, per cent	21.10	19.98	17.90	19.74	19.02	25.55	18.66
Secondary alkalinity, per cent	0.30	0.84	1.90	0.02	0.06	0.04	0.02
Chloride salinity, percent	90.30	92.08	92.72	99.62	99.94	99.96	99.80
Sulphate salinity, per cent	9.24	7.08	5.38	0.35	None	None	0.18
Iron, parts per million	.....	22	42	117	48	52	63
Calcium, parts per million	420	1,779	1,350	4,950	6,710	7,440	5,663
Magnesium, parts per million	1,300	464	377	1,915	2,762	2,960	2,935
Sodium and potassium, parts per million	11,100	11 146	9,318	34,452	49,298	37,026	52,652
Bicarbonate, parts per million	.....	313	587	10	68	41	40
Sulphate, parts per million	2,700	2,086	1,310	252	Trace	Trace	236
Chloride, parts per million	19,410	20,007	16,640	67,300	95,800	78,800	99,640

In the Blackwell field the results are relatively similar, though the concentration is higher. (The oil horizons are at 1,700 feet and 3,400 feet.)

	OIL SAND	WATER SAND	
	Water from depth of 3,412 ft.	*Water from depth of 2,640 ft.*	*Water from depth of 2,226 ft.*
Primary salinity, per cent	78.24	93.06	87.97
Secondary salinity, per cent	21.71	6.93	12.02
Secondary alkalinity, per cent	0.05	0.01	0.01
Chloride salinity, per cent	99.59	99.99	99.99
Sulphate salinity, per cent	0.36	None	None
Iron, parts per million	174	185	52
Calcium, parts per million	2,407	3,412	5,950
Magnesium, parts per million	9,353	2,470	3,855
Sodium and potassium, parts per million	62,098	104,079	91,276
Bicarbonate, parts per million	58	21	25
Sulphate, parts per million	475	None	None
Chlorides, parts per million	126,800	173,680	162,240
Total solids, parts per million	201,356	283,847	263,398

PART XII

SOME GENERAL CONCLUSIONS

It was intended to relate in this book the facts about the oil, rather than to theorize as to its origin and accumulation. In all the world's oilfields, so many circumstances yet remain obscure that the greater need is for the true presentation and analysis of facts. In this final chapter, however, some conclusions seem inevitable.

The Oil Originated Within the Sediments

In the great oilfield region, above described, it has been shown that the oil occurs in a pile of marine sediments, which still lie almost as they were deposited. There is a general absence of all disturbing factors which might confuse the issue.

No vulcanicity has affected the region, and the deposits are free from igneous intrusions. There are no Saline Domes, Crystalline Plugs, Solfataric Phenomena, or Mysterious Fissures, and there are rather few faults. Further, there is no great structural line or tectonic feature with which the oilfields show any connection, and no conspicuous earth-movement is in progress.

But the oil occurs throught an ancient sedimentary formation, laid down under comparatively quiet conditions; and through all the long ages since, it has continued in repose.

It is therefore concluded that the hydrocarbons certainly have not been introduced by any igneous or volcanic activity. In other words, the oil and gas have not been injected from any subterranean source but have originated within the mass of sediments.

The Carbonaceous Materials in the Formations

The oil-bearing deposits in the Mid Continent Oil Region are of the type usual in oilfields, being a thick pile of sediments consisting essentially of clay-shales alternating with beds of sandstone, the clay-shales predominating and containing vegetable organic matter.

The beds were laid down on a gradually subsiding sea floor, along the coast of a slowly rising land; and the waters in which they were formed were alternately shallow and fairly deep.

In the deposits there is no remarkable quantity of fish-remains, mollusca or diatoms to be recorded, and there is no notable amount of gypsum, salt, or sulphur.

Thin limestone beds are a conspicuous feature of the Pennsylvanian oil-bearing formations in Kansas and Oklahoma, but the oil accumulations do not appear to be dependent in any way on these limestones; for, in the richest part of the oil region in Oklahoma, there is less limestone than in the poorer parts of the region, or in other parts where there is no oil. In some instances, however, sandy bands within these limestones are occupied by oil, but at the same time, it must be recorded that plant-bearing shales are sometimes found in immediate contact with the limestones.

In the Bend Limestone of north central Texas there is now a great production. The oil is struck in sandy and shaly horizons within this thick limestone series but there is no good reason to suppose that the oil originated from the limestone rocks. It must be observed that thick black carbonaceous shales lie above and below, and that in these also production is being obtained.

Coal seams are present at intervals throughout a great part of the oil bearing formations (the Pennsylvanian of Kansas and Oklahoma), and much of the clay-shale and sandstone contains abundant carbonaceous particles derived from plants.

In the Cherokee Series, which includes the principal oil sands, there is generally more coal, more sandstone and less limestone, than in the other members of the System. The Cherokee Series is particularly rich in carbonaceous matter, of vegetable origin; but the actual coal-seams appear to be quite independent of the oil.

Vegetable Matter the Probable Source

The most probable source of the hydrocarbons is the vegetable matter which was imprisoned in the deposits.

Closely associated with the oil-sands, commonly there are thick beds of dark, sometimes almost black, marine clay-shales, which contain small carbonaceous plant particles abundantly. Indeed a large proportion of the Shales (which compose the greater part of the accumulations) certainly enclosed plant remains in more or less amount. Even now the presence of carbonaceous matter is generally perceptible in them.

A minute percentage of vegetable matter in these rocks would account for all the oil and gas of the Mid Continent fields,—as the following figures will show.

The total quantity of oil extracted from the Mid Continent Oil Region will be about 1,268 million barrels at the end of 1919. The actual area from which it has been raised could be inclosed in 2,500 square miles. The average yield of oil over this large area is 792 barrels per acre.

The area throughout which the oilfields are spread is about 10,000 square miles, and we may, perhaps, assume that the accumulations of oil have been collected together from all over this larger area.

If the oil were re-distributed over this ground, it would cover the whole of it to a depth of .309 inches; and this corresponds to 1.18 pounds of carbon per square foot of territory.

The quantity of gas which has been released from the same ground is estimated at 1,800,000 million cubic feet, up to the end of 1919. If this, likewise, could be spread over the same 10,000 square miles, we should have a layer of gas 77.4 inches deep; and this would correspond to .20 pounds of carbon per square foot of territory.

Thus, the oil and gas together would correspond to 1.83 pounds of carbon per square foot.

Even at this present time, there is still far more than 1.38 pounds of carbon per square foot of territory, in these deposits. In the sandstones alone, without drawing upon the shales, there is still much more than this amount.

Taking the thickness of the deposits to be 4,000 feet, and the area drained to be 10,000 square miles, then the quantity of carbon required to produce all the oil yet taken out of the Mid Continent Fields, would be only .00023 per cent of the whole mass of sediments.

It may safely be stated that a mere fraction of the vegetable carbonaceous matter in the Pennsylvanian sediments would have been ample to form all the hydrocarbons which they now contain,—provided the necessary chemical transformations could be effected.

Relation Between Shore-lines and Oilfields

Another interesting matter is the relation between the oil and the shore-lines of the deposits.

On the general map of the region, it is seen at a glance that the rich fields of east Kansas and northeast Oklahoma, which draw their oil from the Cherokee Series, lie in a belt which parallels the eastern shore line of the Pennsylvanian Sea, at a distance of 20–60 miles.

This shore line was shifting its position westward, from time to time, as the Period progressed, and so we cannot tell just what was the distance from the mainland at which each petroliferous deposit was formed, but it appears likely that this distance generally was between 10 and 40 miles.

In central Kansas, the now buried ridge—the Nemaha Mountains—probably played an important rôle, by providing near-shore conditions which have resulted in the great oil wealth of Butler County (Kansas). The southward extension of this ridge may account also for the oilfields of Kay County, etc. (Oklahoma).

Again, in southern Oklahoma, a belt of oilfields extends west of the main fields, adjacent to the line of the Wichita and Arbuckle uplift-masses of older racks. These fields are within 10–20 miles of the shore line of the Permian deposits.

The oilfields of north Texas (Wichita and Clay Counties) are adjacent to the line of a buried uplift, known as the Red River uplift. Presumably there was land here during part of the Pennsylvanian Period,—and thus near-shore conditions existed for the Pennsylvanian deposits of these fields.

In north central Texas the conditions are more obscure, but the evidence suggests that a line of uplifting underlies this belt of fields, extending northward from the Llano-Burnett uplift to the Wichita-Arbuncle uplifts. Thus, here also, land may have been near at hand when the oil-bearing Bend Series was laid down.

Migration of the Oil and Gas

The transfer of the oil and gas particles, from their birthplace in the sand and shale, to their final place of accumulation in the porous beds of these great sheets of almost horizontal strata, is an interesting problem, and many theories have been put forward.

In all cases, below the oil in an oil sand (that is to say, lower down the dip), the sand is occupied by water. The oil and gas are resting on the water in accordance with the dictates of gravitation.

This "under-water" differs as regards its chemical contents from the waters that are found near the surface ("upper-waters"), which have entered the sands at the outcrops. In some cases, its resemblance to sea water is pronounced. The under-water (often called connate water) is supposed to be a remnant of the sea water with which the sediments must have been saturated when first deposited.

Under the gradual compacting of the sediments, due to their own weight, much of the connate water must have been squeezed out of the clays; and subsequently it has been moved to and fro along the more porous beds whenever any deformation of the rocks occurred.

Perhaps the three most obvious movements of the oil and gas were:—

(1) The squeezing out of the oil and gas particles, along with connate water, from the places where they originated in the shales and sands, into the most porous seams, where they coalesce to form globules of oil and bubbles of gas.

(2) The rising of the globules of oil and bubbles of gas through the water to the top of it, under gravitational force.

(3) The movement of bodies of oil and gas along porous beds, propelled by the connate water, which may be squeezed to and fro by continued deformation of the mass of strata.

These various movements have resulted in a general migration of oil and gas up the monocline (generally from west to east) towards the outcrop.

The greatness of these oilfields is partly due to the magnitude of the monocline, and to its long and quiet life.

Just at what stage the birth of the hydrocarbons occurred is not known. Possibly the generation of the oil and gas, and the deformation of the sediments and also the migration up the dip, have all been in progress together and continually.

Accumulation of Oil and Gas

In many cases, no doubt, the hydrocarbons have reached the surface and have been dissipated; but at hundreds of places their progress towards the outcrop has been checked, and an accumulation of oil and gas has been held back by some barrier.

These oil and gas "pools" somewhat resemble gigantic bubbles, and the places where they have lodged are giant "bubble traps."

The most obvious barriers to the migration of the oil in a sandstone, up the dip, are:—

(1) A reversal of dip,—(which usually has resulted in a syncline filled with water).

(2) The termination, or sealing-up of the sheet of sandstone before reaching the surface.

Accordingly, the oil and gas pools are found mainly in,—

(1) Domes, Anticlines and Terraces.

(2) Lenticular Sandstones.

It has been shown (Part VIII) that among all the oilfields whose structures have been determined, the great majority are situated on domes and anticlines.

Relation Between Gas Pressure and Depth

Throughout the Mid Continent Field there is a persistent relation between the gas pressure and the depth; in fact the pressure corresponds to the hydrostatic pressure of a column of water having depth equal to the depth at which the gas-sand lies.

There is much difference of opinion as to the cause of this pressure, and its relationship.

In any outcropping series of strata the sandstones are more or less saturated with water, which has entered from the surface. The water may extend down the dip for a number of miles from the outcrop, and may attain a depth of several hundred feet, or a thousand feet, or more.

These "upper" waters, as already stated, are quite distinct from the "under" waters, their chemical contents being different.

Presumably, at some depth, the upper-water will meet the under-water, and some admixture may take place, though, owing to friction and lack of circulation, the mixing effect probably is small. But, though they may not mix very much, the two waters will join and become one continuous body of fluid in the matter of transmitting pressure to and from the pools of oil and gas.

Provided there is continuity of the fluids along the sand all the way from the gas pool to the upper-water, the hydrostatic pressure on the gas is a natural consequence.

However much gas may be brought into the reservoir, or generated in it, the pressure is limited to that prescribed by this hydrostatic pressure. If the gas pressure is increased, for an instant, beyond this limit, some gas will force its way out towards the surface until the equilibrium pressure is restored.

The relationship is found only to hold good for the initial pressure in the pool, and the decline of pressure, when the gas is released, is considered by some oil men to be evidence against the hydrostatic theory. It is necessary, however, to make large allowances for the friction in the rock. It takes considerable time for the water to flow in through the sand. In a number of instances it has been demonstrated that if the gasfield is shut down for a period—although the field is nearly exhausted of its quantity of gas—the original pressure (though not the volume) can be regained, if sufficient time is allowed.

One of the difficulties in the way of the hydrostatic explanation is that the same relationship appears to hold true even in those gas pools which are supposed to occupy lenticular sands which do not reach the surface at all; but on this matter more data should be obtained before it is accepted as a fact that no fluid connection with the surface exists.

Applicability of White's Law

The interesting "laws" recently formulated by Dr. David White, which are well established in the West Virginia Oil region, are generally considered to apply satisfactorily also in the Mid Continent fields. These laws stated:—

(1) "In regions where the progressive devolatilization of the organic deposits in any formation passed a certain point, marked in most provinces by 65 to 70 per cent of carbon (pure coal basis) in the associated or overlying coals, commercial oil pools are not present in that formation, nor in any other formation normally underlying it; though commercial gas pools may occur."

(2) "The lowest rank oils of each type are found in the regions and formations in which the carbonaceous deposits are least altered, . . . the highest rank oils being, on the whole, found in regions where the carbonaceous deposits . . . have been brought to correspondingly higher ranks."

The idea underlying the laws, is that there has been a progressive chemical change among the hydrocarbons, as with the coals, under the influence of time and compression.

According to Johnson and Huntley:—

"The increased dynamo-chemical activity with increased depth and increased folding, produces a continual evolution of gas and oil from the organic detritus, and to a much less degree from the previously formed oil; that the successive quantities become increasingly gaseous, and those that are liquid lighter and lighter, as the dynamo-chemical agency becomes more intense."

In accordance with these laws, the older formations, such as the productive formations of the Mid Continent region, contain light oil and much gas, whilst newer formations, such as the Tertiary in the California fields or in the Gulf Coast fields, contain heavy oil and very little gas.

In the one district in the Mid Continent fields in which the oil-bearing formation is more intensely folded (southeast Oklahoma) and where the coals are of highest quality, gas without oil occurs.

Much more might be said in connection with this interesting matter, but it is beyond the scope of this small book.

Other Theories

For other theories relating to the origin and accumulation of oil and gas,—the conclusions of Orton, Munn, Clapp, White, Arnold, Washburne, and others,—and their bearing on the Mid Continent Fields, the reader must be referred to larger works, for the purpose of this volume is simply to give a fair presentation of the established facts concerning this great oilfield region.

In Conclusion:

In conclusion, the author wishes to express his appreciation of the work of the many geologists, scientists, oilmen, and oil journalists, whose discoveries, maps and writings have indirectly contributed to these pages.

Doubtless, many errors will be found, many important matters have been omitted and most of the information is very incomplete; but, in view of the largeness of the subject, some indulgence is hoped for from all fellow workers in this great field.

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The following data are from some of the large plants in the Mid Continent fields. (Bureau of Mines.)

FIELD	*Plant No.*	*Gas per day in millions cu. feet*	*Barrels of gasoline produced per day*	*Yield, gallons per 1,000 cu. feet*	*Sp. gr. of gasoline*
Glen.............	32	3.0	539	7.40	.654
“	33	1.8	214	5.00	.660
“	36	2.0	55	1.10	.673
“	34	0.75	125	7.00	.660
“	48	1.2	57	2.00	
Morris...........	44	0.5	44	3.60	
“	58	2.0	71	1.50	
Cushing..........	49	2.0	67	1.40	
Cleveland.........	50	1.2	48	1.67	
Muskogee........	51	0.25	22	3.70	
Nowata..........	54	2.25	238	4.00	
“	55	1.25	38	1.30	
“	60	1.00	45	1.90	
Beggs............	45	0.35	17	2.10	

Production of Casinghead gasoline in the Mid Continent Field, by the compression process during 1917, is estimated;—

	Number of plants	*Millions of cu. ft. of gas treated*	*Gasoline produced, (barrels)*	*Gallons per 1,000 cu. ft.*
Kansas..............	1	41	2,460	2.5
Oklahoma...........	207	36,399	2,588,766	2.987
North Texas.........	8	2,800 (?)	100,000 (?)	1.5 (?)

Thus, the production by the compression process in the Mid Continent Oilfields during 1917, was over $2^2/_3$ million barrels, the average yield being near 3 gallons of gasoline per thousand cubic feet.

CHAPTER III

PRODUCTION BY THE ABSORPTION PROCESS

The Absorption Process, which has come into use in the past four years, is applicable to the ordinary kinds of natural gas, which occur in great abundance throughout the region. It is being installed in many fields, and is likely to become more important than the Compression Process.

At present the two processes are used for two different types of gas.

Ordinary natural gas, containing less than 1 gallon of gasoline per thousand feet, was too "lean" to be profitable under the Compression Process; and previous to 1916, only the exceptionally "wet" gas, drawn fron oil wells, was generally utilized as a source of gasoline.

But the Absorption Process is giving profitable results with almost any gas in the region—"lean" gases containing only ½ a gallon of gasoline per thousand cubic feet, and even "dry" gases which yield no more than a tenth of a gallon per thousand cubic feet.

The process consists in passing the gas through an oil heavier than gasoline, which absorbs the gasoline from this gas by solution. The gasoline is then recovered by fractional distillation. Another method is to pass the gas through a very light refined oil until sufficient gasoline is absorbed to bring the solution to the density of commercial gasoline.

The operation is not expensive, and the gasoline obtained is a valuable by-product at pump stations on pipe-lines handling large quantities of gas.

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The upper-waters contain a much greater amount of total solids, and but little or no sulphates. The under-waters contain a much less amount of total solids, but a considerable quantity of sulphates.

In the Augusta and Eldorado fields, some hundreds of water samples were analyzed. It is conclusively shown that the water below the oil, in the main oil sand (Varner Sand, 2,500 feet), differs from the water in the water sands above, in that—

(1) It contains only about one-third as much solids in solution.
(2) It contains a conspicuous quantity of sulphat.

The water in this sand has almost constant composition throughout the oilfield. The waters of the other sands differ among themselves in some degree, but all have the above-mentioned wide difference from the water of the Varner Sand.

This fact is of practical use, for when water is struck at about the depth where oil was hoped for, a chemical test discloses whether or not the oil sand has been reached.

The water in the Varner Sand bears a close resemblance to sea water. This, however, is probably a coincidence, for the chemical contents of the water will have undergone many changes during the long imprisonment of the water in the rocks and the alterations in temperature and pressure which have occurred.